B6800-1

NUEXCO

DECEMBER 1984 NUMBER 196

MONTHLY REPORT

ON THE NUCLEAR FUEL MARKET

NUEXCO

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MONTHLY REPORT ON THE NUCLEAR FUEL MARKET

December 1984 No. 196

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To Our Readers

We are pleased to announce that Mr. **Wayne Fowler,** Senior Vice President in charge of Nuexco's US and Far East brokerage operations, has been named President and Chief Operating Officer effective December 1, 1984. Wayne succeeds George White, Jr., who will move to the position of Senior Consultant–Marketing. The restructuring coincides with Nuexco's planned relocation of our company headquarters to Atlanta, Georgia. The relocation, which will take place during 1985, is one of a series of steps to centralize operations in the Eastern time zone and improve proximity to most of our clients. Since much of the nuclear fuel brokerage business takes place in the Eastern USA and Europe, Nuexco believes that better and more efficient service will be realized by locating in Atlanta. We will continue, however, to maintain an office in Menlo Park to facilitate business with the western states and the Far East. Mr. Fowler, currently located in Nuexco's Northeast Regional Office in Stamford, Connecticut, will relocate to Atlanta in early 1985.

* * *

Nuexco's US offices will be closed for the Christmas holiday on Monday and Tuesday, December 24 and 25, and Monday and Tuesday, December 31 and January 1. Nuexco's European office will be closed December 24 through January 1.

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NATURAL URANIUM AND SECONDARY MARKET CONVERSION

The **Exchange Value** as of November 30, 1984 is **$15.50** per pound U_3O_8, down $0.50 since last month. **Active supply** of natural uranium (U_3O_8 and UF_6) for spot or near-term delivery totals **5,240,000** pounds U_3O_8 or equivalent UF_6, down 21,000 pounds since last month. The corresponding figure for **active demand** is **1,310,000** pounds, up 35,000 pounds. The spot and near-term **supply-demand ratio** fell to **4.0:1.**

The *Current Market Data* section of this Report lists three uranium sales transactions, involving a total of approximately 9,800,000 pounds equivalent U_3O_8. All of those sales involved natural UF_6. Two of the transactions reported this month involved deliveries before 1986, and one met the criteria for inclusion in the current Transaction Value calculation.

The **Transaction Value** as of November 30, 1984 is **$15.90** per pound U_3O_8, down $0.15 since last month. The current Transaction Value includes 11 transactions involving a total of 3.5 million pounds U_3O_8 or equivalent UF_6 and covers a period of 6 months.

The **Loan Use Charge Rate** as of November 30, 1984 is **6 percent** per annum, unchanged since last month in a dormant market.

* * *

The Exchange Value declined to $15.50 largely because of the presence of a major transaction that was concluded at a price well below $16.00. The low activity prevalent for the past several months enhanced the importance of that transaction, since much of the current supply is available at the $16.00 level. In addition, at least two sellers offered significant quantities of material below $15.50, exerting downward pressure on November's Exchange Value.

The general lack of activity this month represents a continuation of the trend exhibited over the past several months in the sale of natural uranium. Sellers have been forced to lower prices substantially to satisfy opportunistic buyers. While the discretionary demand actions by most buyers indicate utilities' lack of interest for immediate forward supply, financial considerations could motivate some sellers to make concessions in order to close deals before January 1. The drop in offering prices that occurred at the end of November failed to draw much new demand into the market. It is still unknown whether buyers will emerge in December unless prices drop still lower.

* * *

The **Conversion Value** is **$0.80** per pound U in UF_6, down $0.20 since last month. The presence of highly discretionary demand precluded the likelihood of purchases at the $1.00 level. Several offers in the $0.80 range combined with counter-bids below that level drove down the Conversion Value. Active supply of secondary market conversion services for delivery within three years amounts to 1.2 million pounds U in UF_6. No active secondary market conversion demand for delivery within three years, and no secondary market conversion transactions, are reported.

ENRICHED URANIUM AND SWUS

The Nuexco **SWU Values** as of November 30, 1984 are:

1. For **DOE origin,** a tails assay of 0.30 weight-percent U_{235}, and certifiable as excess:
   a. For FY85 delivery, $115 per SWU, unchanged;
   b. For FY86 delivery, $15 discount from the USEC base price on delivery, down from $20 last month;
2. For **other** SWUs (includes DOE origin SWUs not certifiable as excess and non-DOE origin SWUs):
   a. For delivery within approximately 15 months, $85 per SWU, down $5;
   b. For delivery in CY86, $95 per SWU, down $3.

Seven secondary market SWU transactions are reported, involving 370,000 SWUs. Active secondary market SWU supply amounts to 475,000 SWUs, while active demand totals 125,000 SWUs.

* * *

The price for DOE origin SWUs certifiable as excess for FY85 appears to be firming, as many November offers were above the $115/SWU level. However, a significant quantity was available for $115/SWU on the last day of the month. Most of the demand for FY85 deliveries has been filled, and few buyers are actively soliciting offers. Many buyers are now focusing on the FY86 market, and with the presence of increasing demand, the discount levels are falling. However, at this early date for FY86 SWUs certifiable as excess, there is wide disparity between the prices sellers are willing to accept and the prices buyers are interested in paying. Consequently, many buyers wanting to purchase FY86 SWUs are waiting in the hopes of getting a better deal. Certifiable FY86 supply is limited, however, because the USEC allowed holders of excess to draw down inventories or reduce by 25 percent previously scheduled AFC deliveries. The buyers of certifiable FY85

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and FY86 SWUs consist mainly of former holders of Requirements-type contracts that signed the USEC for less than 100 percent of their needs.

The market for SWUs of other origin, including DOE SWUs not certifiable as excess and non-DOE SWUs, appears to have little short-term activity in the wake of the USEC signings by many non-US utilities. There is little short-term demand because most such buyers have already purchased and prices are weak. Sellers are trying to generate demand while a few deals in which the certification has been in question wait to be resolved. The majority of buyers interested in other origin SWUs for calendar year 1985 and 1986 comprise two groups:

1. Those that have unfilled requirements and did not sign the USEC, and
2. Those that had signed the USEC and had terminated deliveries in the CY85-86 period prior to December 1983.

Non-DOE SWU suppliers can look to the post-FY86 market for the most activity and interest. All DOE customers that signed the USEC for less than 100 percent of their requirements will be able to fill their remaining requirements from any source, and non-DOE enrichment suppliers will be competing actively for this business. Utilities can expect substantial discounts as more utilities enter the post-FY86 market in the next several months and begin evaluating suppliers' proposals.

Future DOE offers can be expected for this large class of long-term requirements buyers that will emerge soon. Although Cogema and Urenco are price leaders now, DOE's price-cutting strategy and upcoming decision on technology, expected in May 1985, could greatly influence the market for other SWUs after FY86. Many potential buyers will continue to await DOE offers for this portion of demand before selecting a supplier.

DOE: BUSINESS OR GOVERNMENT SERVICE?

In August 1984, testimony was given before the Tri-Committee Advisory Panel on Uranium Enrichment. One of the persons asked to give testimony was Nuexco's CEO, J. Robert Wolcott. A main theme of his testimony was the apparent conflict in objectives arising from whether DOE should be considered a business or a government service. DOE's former assistant secretary for nuclear energy, Shelby Brewer, testifed before the panel, stating DOE's inclination to run as a business. As a result of the testimony, Mr. Wolcott reflected on some of DOE's recent actions as they pertain to its most recent business orientation. Those reflections, following a brief history of the DOE enrichment organization, are summarized below.

Introduction

In the 1960s, the US Government was committed to supporting the nuclear power industry, a commitment which manifested itself in several ways including guaranteed purchases of uranium ore from producers and leasing of fuel to fledgling nuclear utilities. This latter activity required the Government to provide enrichment services to the free world. Presumably, these services were provided because nuclear power was deemed to be a desirable energy source and the Atomic Energy Commission (AEC) was the only entity in the free world capable of providing such a service on a commercial scale. Separative work production was inexpensive and the national interests were well served through the promise of safe, cheap nuclear power and the spreading of fixed enrichment costs over a large international customer base.

In its enrichment enterprise, the AEC was clearly a *service* organization. The early days of private ownership of nuclear fuel saw the same theme carried into the Requirements-type contract where the AEC continued to provide enrichment services as needed on a toll basis (and thus the origination of the term "toll enrichment"). However, in the 1970s several initiatives arose in an effort to provide a more businesslike orientation to AEC's enrichment operations. The goal of these initiatives was ultimately to privatize the supply of enrichment services. Among the shopping list of such initiatives was commercial value pricing, fair value pricing, the Industrial Access Program and the Industrial Participation Program. There were others as well, but the one initiative that has had the most dramatic effect on the nuclear power industry was the introduction of the Long-Term, Fixed Commitment (LTFC) contract. The LTFC contract shifted much of the risk of supply to the customer and thus put the supply of enrichment services on a more "businesslike" basis, notwithstanding the fact that the AEC had a virtual monopoly at the time.

The stage was set for the enrichment enterprise to be turned over to private industry. Coincidentally, in concert with several unrelated events, AEC set the stage for the development of large unanticipated enrichment inventories and the evolution of the secondary market for enrichment services. Later in the decade, the goal of privatization died a quiet death with the failure of Congress to pass the Nuclear Fuel Assurance Act of 1976, and in the

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following year, a new period with renewed emphasis on Government control of the enrichment enterprise would begin.

The passage of the Department of Energy Act and the abolition of the Joint Committee on Atomic Energy had similar effects on their respective branches of Government. Neither the Executive Department nor Congress had single entities whose sole function was to monitor and aid the development of the nuclear industry. Thus enmeshed in the bureaucratic maze, the enrichment enterprise settled into the comfortable position of providing a Government service and moved to perpetuate its existence by pursuing the planning and construction of the centrifuge add-on facility at Portsmouth, Ohio.

The Department of Energy (DOE) relaxed the burden imposed on the nuclear utilities by the LTFC contract with the introduction of the Adjustable, Fixed Commitment (AFC) contract which was in itself a rather burdensome compromise between its two predecessors. One effect of this new contract was to spur secondary market activity and encourage the development of enrichment brokerage operations.

Paralleling this brief history is the development of international enrichment enterprises and the inadvertent buildup of non-DOE separative work unit (SWU) inventories. Inevitably, these non-DOE SWU inventories found their way into the USA via the secondary market encouraged by the astronomical increases in DOE SWU prices during the 1970s and early 1980s. DOE lost billions of dollars to competition in the secondary market, a position which they quickly considered untenable. DOE thus launched a series of moves to combat this unwanted competition culminating in the development of the Utility Services Enrichment Contract (USEC) and its associated conversion terms. Along with the new contract came yet another change in orientation, this time from a service approach to an avowed businesslike approach.

Full Cost Recovery

DOE is required by law to recover full costs "over a reasonable period of time." Using April 1984 data, DOE has argued that a ceiling price of $135 will allow it to recover full costs. DOE uses 10 years as a reasonable period, and over that period, GAO estimates DOE will lose over $3 billion.

DOE estimates that it will sell 192.2 million SWU during the period fiscal year 1985 through fiscal year 1994. Costs during the same 10-year period were forecast at $25,815 million. Dividing projected costs by projected sales, DOE arrived at a *breakeven cost* of $135 per SWU. In other words, if DOE sold all the SWU and spent all the money forecast, they would break even if *all* SWU during the 10-year period were sold at $135 per SWU in FY85 dollars.

However, DOE has also produced a chart which shows projected SWU prices. In this case, the $135 SWU cost, as calculated above, is shown as a *ceiling*, not as projected cost. Prices are forecast to decline to about the $105 to $110 per SWU range by 1994 and declining further from there. At forecast *prices*, the revenue from sales would be about $15 per SWU less projected cost, or ceiling price, for a total loss of almost $3 billion.

In order to reconcile these apparently conflicting data, one need only recognize that DOE adjusts its prices annually on a *rolling* ten-year campaign. Thus, as long as costs per SWU are forecast to decrease in the tenth year, the new breakeven cost will be lower than that calculated the previous year. (Of course, there is some limit below which costs no longer can decline, and at this point the breakeven costs will reach an equilibrium.)

It is this phenomenon that led the GAO to the conclusion that DOE would lose $3 billion over the 10-year period. For example, the April 1984 DOE data projects FY89 sales to be 14.3 million SWU. At a price of $135 per SWU, FY89 revenues would be $1.93 billion. If the next 10-year pricing campaign arrives at a $125 per SWU breakeven cost, the FY89 revenues drop to $1.79 billion in *FY86 dollars*. Translated into FY85 dollars at 7% inflation, the latter projection indicates that DOE will collect $260 million less in FY89 than was necessary to break even at the higher SWU price. This phenomenon would be the same for each of the remaining nine years in the old pricing campaign.

Such a methodology is hardly acceptable to a business concerned with rewarding shareholders for their investment.

DOE Market Forecast

Over the years, DOE's successive market forecasts have proven to be overly optimistic (as have many forecasts). The DOE sales forecast in the April 1984 data estimates sales of a little over 14 million SWU in 1985 and over 23 million in 1994, an increase of 60%. The sales forecast is nearly flat through 1989 on a 14-million-SWU plateau. During 1990 and 1991, it rises to about a 23.5-million-SWU plateau through 1994, a rise of almost 70%.

Nuexco forecasts that free world SWU consumption in 1994 will be 32 million SWU. US consumption will plateau at 12 million about 1988. Assuming that the DOE sales and Nuexco consumption forecasts agree, DOE will

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supply 70% of world consumption in 1994. Even without allowing for any non-US supplied secondary or primary market SWUs used in the USA, DOE production will have to be double the US consumption. DOE must sell more SWU overseas than in the USA to meet their sales forecast. World market share must *increase* despite growing competition.

However, DOE is losing market position in part because of nationalism; the forces of nationalism are permanent, and further erosion is to be expected even if we cannot predict the precise timing.

A business would have to consider the possibility of a market share of only 25% or 50% in excess of US consumption. (A market position that a private US energy exporting company would consider very favorable.)

DOE's April 1984 Pricing Campaign

The table below is derived from DOE's April 1984 pricing campaign by dividing DOE costs by DOE sales.

Fiscal Year	Cost Per SWU	Loss(Gain)/ SWU (@ $135/SWU)	Annual Loss (Gain)	Cumulative Loss
1985	$256.88[1]	$(121.88)	$(1,709,976,000)	$ 1,709,976,000
1986	152.42	(17.42)	(241,615,000)	1,951,591,000
1987	153.76	(18.76)	(254,760,000)	2,206,351,000
1988	173.32	(38.32)	(483,981,000)	2,690,332,000
1989	176.50	(41.50)	(593,450,000)	3,283,782,000
1990	141.95	(6.95)	(131,702,000)	3,415,484,000
1991	115.50	19.50	462,930,000	2,952,554,000
1992	117.78	17.22	413,452,000	2,539,102,000
1993	112.79	22.21	514,161,000	2,024,941,000
1994	104.80	30.20	698,828,000	1,326,113,000
		Less ending inventory		$(1,326,113,000)
		Net		$0

[1]The 1985 Cost per SWU is misleading in that beginning inventory appears to be expenses in that first year. If beginning inventory is subtracted out, the FY85 cost per SWU is $147.40.

The table above shows that DOE expects to accumulate costs in excess of revenue from sales of approximately $3.5 billion by FY90. Beginning in FY91, costs are less than the SWU price, and the cumulative loss begins to decrease. Since the operation is nonprofit-making, one expects a final cumulative loss to be offset by ending inventory, so this result is not surprising. What is significant, however, is that a positive margin in any year is not experienced until FY91.

A Hypothetical Scenario

Assume for the purpose of this analysis that DOE did several things which are within its power to do. These actions involve making decisions which do not conflict with customer obligations or reliability of supply and are therefore at DOE discretion. The hypothetical, but possible, decisions are as follows:

1. Stop all further investment so that depreciation remains at the current level of $76 million per year.
2. Maintain interest at the same level by deferring investment. Interest would be $553 million per year.
3. Reduce R&D *now* to the level planned for *1991*. That is $20 million per year.
4. Wait for the TVA contract to run out. Use low-cost power sources. Assume the cost of $699 million, as estimated for FY94, is increased 10% to account for diffusion production rather than gas centrifuge, thus making the power bill approximately $770 million per year. Assume all other costs to be the same. The estimated effect (in millions of dollars) of these actions would be as follows:

Power	$770
Operation	399
Depreciation	76
Interest	553
R&D	20
Miscellaneous	-60
Total	$1,758

Providing DOE sold 23.14 million SWU as they forecast, cost for 1994 would be approximately $76 per SWU rather than $105, as they estimate for the course they are presently pursuing.

Furthermore, it is interesting for purposes of sensitivity analysis to compare per unit SWU costs assuming all costs remain constant except sales volume. Assuming two-thirds of the DOE sales volume (or 15.5 million SWU over the 10-year period), the projection would yield:

	Cost Per SWU
Before hypothetical adjustments	$156.45
After hypothetical adjustments	$113.42

The current DOE program would lose $50 per SWU in the event the projected market does not materialize. Under the hypothetical case, the loss would be limited to $37 per SWU. The reason is that high investment and interest charges increase fixed charges. DOE is less capable of adjusting to lower volume. The probability that DOE will realize sales in excess of 23 million SWU per year is very low. The probability of settling for a lower sales volume is very high.

While one cannot draw specific conclusions from the hypothetical case, it is presented as an opinion to stimulate thought. Undoubtedly, DOE's pricing policy will come under increased scrutiny as Congress is asked to comment on incentive pricing and as the date for selection of replacement technology approaches.

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CURRENT MARKET DATA

November 30, 1984	Market Values	Active Supply[1] (thousands)	Active Demand[1] (thousands)
EXCHANGE VALUE	**$15.50**/lb. U_3O_8	5,240	1,310
CONVERSION VALUE	**$0.80**/lb. U in UF_6	1,225	0
SWU VALUES		475	125
DOE origin, certifiable as excess, 0.3 tails assay			
FY85 delivery	**$115**/SWU		
FY86 delivery	**$15** discount/SWU		
Other SWUs (non-DOE or non-certifiable)			
delivery within 15 months	**$85**/SWU		
delivery for calendar year 1986	**$95**/SWU		
LOAN USE CHARGE RATE	6%/annum	0	0

TRANSACTION VALUE

$/lb. U_3O_8	Millions of Pounds	Number of Transactions	Number of Months
15.90	3.5	11	6

[1]Supply and demand tables in the *Current Market Data* section of this Report detail the numbers for each category. Quantities of SWUs (Separative Work Units) are not referenced to a particular origin.

DEFINITIONS

1. The **Exchange Value** is Nuexco's judgment of the price at which transactions for significant quantities of natural uranium concentrates could be concluded as of the date indicated.
2. The **Conversion Value** is Nuexco's judgment of the price at which spot and near-term transactions for significant quantities of conversion services could be concluded in the secondary market as of the date indicated.
3. The **SWU Values** represent Nuexco's judgment of the price at which transactions for the sale of significant quantities of SWUs of stated origin for delivery in the specified time period could be concluded as of the date indicated.
4. The **Loan Use Charge Rate** is Nuexco's judgment of the annual interest rate at which uranium loans could be concluded as of the date indicated.
5. The **Transaction Value** is a weighted average price of recent natural uranium sales transactions. The calculation is based on prices paid in:
   a. Transactions closed within the previous three-month period for which delivery is scheduled within one year of the transaction date;
   b. At least ten transactions;
   c. Transactions involving a sum total of at least 2 million pounds U_3O_8 equivalent.

   The sample time is extended as necessary to include these minima. Other currencies are converted to US dollars using conversion rates in effect on or near the transaction date.

DERIVATIONS AND COMMENTS

1. All Market Values are based on:
   a. Data from recently completed transactions.
   b. Data from pending transactions.
   c. Firm bids to buy or borrow, and firm offers to sell or lend.
   d. Prices purchasers or rates borrowers have expressed a willingness to pay, but for which Nuexco is not aware of firm bids to buy or borrow, and prices sellers or rates lenders have expressed a willingness to offer, but for which Nuexco is not aware of firm offers to sell or lend.
2. Prices associated with deliveries under old or renegotiated contracts or other than arm's-length transactions are not considered in the determination of these Market Values.
3. In the determination of the Conversion Value, Nuexco does not consider transportation charges other than those customarily provided by primary suppliers of conversion services.
4. The prices of conversion services or SWUs delivered under long-term contracts with primary suppliers are not considered in the determination of either the Conversion Value or SWU Value.
5. For the DOE SWU Values, Nuexco converts SWU prices at varying tails and product assays to equivalent SWU prices at a tails assay of 0.30 weight-percent U_{235} and a product assay of 3.0 weight-percent U_{235}, assuming feed costs corresponding to the Nuexco Exchange and Conversion Values determined as of the same date.
6. In calculating the Transaction Value, Nuexco does not account for the price of uranium delivered in connection with contracts which call for "market price" mechanisms. This exclusion applies particularly to contracts in which delivery prices are expressed as a function of future Exchange Values or any other indeterminant variable. Also excluded from the calculation are any other transactions in which the delivery price is defined in such a way that it cannot currently be determined.

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CURRENT MARKET DATA

EXCHANGE VALUE EXPRESSED IN SELECTED PRODUCER & CONSUMER CURRENCIES[1]

Country (currency)	per lb. U_3O_8 in Concentrates			per kg. U in Concentrates		
	This Month (Nov. 30, 1984)	Last Month (Oct. 31, 1984)	12 Months Ago (Nov. 30, 1983)	This Month (Nov. 30, 1984)	Last Month (Oct. 31, 1984)	12 Months Ago (Nov. 30, 1983)
Australia (dollar)	17.99	18.90	24.68	46.77	49.14	64.15
Belgium (comm. franc)	959.16	984.62	1,236	2,494	2,560	3,214
Canada (dollar)	20.49	21.08	27.90	53.27	54.80	72.54
Finland (markka)	99.17	101.59	130.51	257.82	264.10	339.30
France (franc)	145.95	149.39	185.64	379.44	388.39	482.63
FRG (mark)	47.74	48.69	61.06	124.10	126.59	158.74
Italy (lira)	29,451	30,177	36,885	76,566	78,454	95,893
Japan (yen)	3,811	3,927	5,276	9,908	10,210	13,715
Netherlands (guilder)	53.65	54.91	68.41	139.48	142.75	177.85
South Africa (rand)	28.62	30.59	26.41	74.42	79.53	68.66
Spain (peseta)	2,663	2,736	3,507	6,923	7,113	9,117
Sweden (krona)	135.85	139.13	179.57	353.17	361.71	466.84
Switzerland (franc)	39.17	40.06	48.96	101.84	104.15	127.27
UK (pound)	12.88	13.18	15.42	33.50	34.26	40.09
US (dollar)	15.50	16.00	22.50	40.30	41.60	58.50

TRANSACTION VALUE EXPRESSED IN SELECTED PRODUCER & CONSUMER CURRENCIES[1]

Country (currency)	per lb. U_3O_8 in Concentrates			per kg. U in Concentrates		
	This Month (Nov. 30, 1984)	Last Month (Oct. 31, 1984)	12 Months Ago (Nov. 30, 1983)	This Month (Nov. 30, 1984)	Last Month (Oct. 31, 1984)	12 Months Ago (Nov. 30, 1983)
Australia (dollar)	18.46	18.96	26.16	47.98	49.29	68.00
Belgium (comm. franc)	983.91	987.69	1,310	2,558	2,568	3,407
Canada (dollar)	21.02	21.14	29.58	54.65	54.97	76.89
Finland (markka)	101.73	101.90	138.34	264.47	264.93	359.66
France (franc)	149.72	149.86	196.78	389.23	389.60	511.59
FRG (mark)	48.97	48.84	64.72	127.31	126.98	168.26
Italy (lira)	30,211	30,272	39,098	78,542	78,699	101,647
Japan (yen)	3,910	3,940	5,592	10,164	10,242	14,538
Netherlands (guilder)	55.04	55.08	72.51	143.08	143.19	188.52
South Africa (rand)	29.36	30.69	27.99	76.34	79.78	72.78
Spain (peseta)	2,731	2,745	3,717	7,101	7,135	9,664
Sweden (krona)	139.35	139.57	190.34	362.28	362.84	494.85
Switzerland (franc)	40.18	40.19	51.89	104.46	104.47	134.91
UK (pound)	13.22	13.22	16.35	34.36	34.37	42.50
US (dollar)	15.90	16.05	23.85	41.34	41.73	62.00

[1]Calculated using currency exchange rates published in the *Wall Street Journal* on November 30, 1984.

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CONVERSION VALUE EXPRESSED IN SELECTED PRODUCER & CONSUMER CURRENCIES[1]

Country (currency)	per lb. U as UF_6			per kg. U as UF_6		
	This Month (Nov. 30, 1984)	Last Month (Oct. 31, 1984)	12 Months Ago (Nov. 30, 1983)	This Month (Nov. 30, 1984)	Last Month (Oct. 31, 1984)	12 Months Ago (Nov. 30, 1983)
Australia (dollar)	0.93	1.18	0.66	2.05	2.60	1.45
Belgium (comm. franc)	49.51	61.54	32.97	109.14	135.67	72.68
Canada (dollar)	1.06	1.32	0.74	2.33	2.90	1.64
Finland (markka)	5.12	6.35	3.48	11.28	14.00	7.67
France (franc)	7.53	9.34	4.95	16.61	20.58	10.91
FRG (mark)	2.46	3.04	1.63	5.43	6.71	3.59
Italy (lira)	1,520	1,886	983.61	3,351	4,158	2,168
Japan (yen)	196.71	245.46	140.68	433.66	541.14	310.15
Netherlands (guilder)	2.77	3.43	1.82	6.10	7.57	4.02
South Africa (rand)	1.48	1.91	0.70	3.26	4.22	1.55
Spain (peseta)	137.43	171.00	93.52	302.99	376.99	206.17
Sweden (krona)	7.01	8.70	4.79	15.46	19.17	10.56
Switzerland (franc)	2.02	2.50	1.31	4.46	5.52	2.88
UK (pound)	0.67	0.82	0.41	1.47	1.82	0.91
US (dollar)	0.80	1.00	0.60	1.76	2.20	1.32

SWU VALUES EXPRESSED IN SELECTED PRODUCER & CONSUMER CURRENCIES[1]

Country (currency)	DOE SWU FY85 (November 30, 1984)	Non-DOE SWU delivery within 15 months (November 30, 1984)	Non-DOE SWU calendar year 1986 (November 30, 1984)
Australia (dollar)	133.49	98.67	110.27
Belgium (comm. franc)	7,116	5,260	5,879
Canada (dollar)	152.04	112.37	125.59
Finland (markka)	735.67	543.83	607.81
France (franc)	1,083	800.38	894.54
FRG (mark)	354.17	261.78	292.58
Italy (lira)	218,507	161,505	180,505
Japan (yen)	28,276	20,900	23,359
Netherlands (guilder)	398.06	294.22	328.83
South Africa (rand)	212.37	156.97	175.44
Spain (peseta)	19,756	14,602	16,320
Sweden (krona)	1,008	744.96	832.60
Switzerland (franc)	290.62	214.81	240.08
UK (pound)	95.59	70.66	78.97
US (dollar)	115.00	85.00	95.00

[1]Calculated using currency exchange rates published in the *Wall Street Journal* on November 30, 1984.

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CURRENT MARKET DATA

RECENT TRANSACTIONS[1]

Uranium Sales

Nuexco Transaction Number	Delivery Period	Approximate Quantity (thousands of pounds, U_3O_8 equivalent)	Approximate Price as Percent of Current E.V.	Seller	Buyer	Remarks
3201	1984	50-100	114	European Entity	European Utility	UF_6. Occurred in mid-1984.
3189	1985	601-1,000	99	Canadian Producer	US Utility	UF_6.
3186	1987-1996	5,001-10,000	see remarks	Canadian Producer	Non-US Utility	UF_6. Price related to market at time of delivery.

[1]Transactions listed are not limited to those in which Nuexco was involved, but also include others of which Nuexco is aware.

Enrichment Services
Secondary Market Sales

Nuexco Transaction Number	Delivery Period[2]	Approximate Quantity[3] (thousands of SWUs)	Approximate Price[4] as Percent of Current SWU Value[5]	Seller Group	Buyer Group	SWU Origin	Remarks
3218	FY85	less than 50	91	US Utility	US Utility	DOE	
3217	FY85	less than 50	97	US Utility	US Utility	DOE	
3209	FY85	50-100	87	European Trader	US Utility	DOE	
3208	FY86	50-100	see remarks	US Utility	US Utility	DOE	Discount was 118% of the current FY86 SWU discount.
3191	FY88	101-300	80	European Entity	European Utility	Eurodif	
3188	FY85	less than 50	R[6]	US Utility	US Utility	DOE	
3187	FY85	50-100	R[6]	US Utility	US Utility	DOE	

[1]Transactions listed are not limited to those in which Nuexco was involved, but also include others of which Nuexco is aware.
[2]Refers to calendar year, not fiscal year.
[3]If tails assay is unknown or unspecified, Nuexco's calculation of SWU quantity assumes 0.30 w/o tails assay.
[4]Price is not normalized to 0.30% tails assay.
[5]Refers to SWU Value that corresponds to SWUs included in transaction. When prices and SWU values are expressed as discounts (e.g., X dollars less than DOE's USEC base price at time of delivery), the percentage refers to the ratio of the *discounts*, not the ratio of the prices.
[6]The notation *R* means that Nuexco either does not know, or that Nuexco has restricted that information to protect client confidentiality.

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URANIUM SUPPLY
(November 30, 1984)

Nuexco Project Number	Delivery Period[1] (Thousands of Pounds U_3O_8) Spot or Near-term[2]	Intermediate or Long-term	Remarks
Available for Sale:			
ACTIVE			
1575	500	500 per year	
1860	400	1,500 per year	
2038	1,000	1,000 per year	UF_6
2288A	40	—	
2288B	295	—	UF_6
2392	35	—	UF_6
2499	15	—	
2516	200	—	
2538*	95	—	
2541*	60	—	
2565*	400	—	
2588*	200	250 per year	1986-90
2648	2,000	—	
2134	—	220 per year	1985-87
2236	—	200 per year	1985-90
2263	—	500 per year	1985-90
2654*	—	1,050	1985-87
TOTAL:	5,240		
INACTIVE			
2191	125	—	UF_6
2275	150	—	
2335	275	—	
2389*	300	—	
2495	130	—	UF_6
2509	1,200	1,600	UF_6
2553	300	—	
2569*	200	—	
2584*	300	—	
0564	—	1,000 per year	1985-90
2271	—	500 per year	1984-88
2297	—	200 per year	1986-89
2326	—	1,000 per year	1989-91
2336	—	250 per year	
2368	—	250 per year	1987-90
2473	—	500 per year	1984-90
2514	—	1,000 per year	
2574*	—	500	UF_6
TOTAL:	2,980		

*New or revised since last month.

[1]Measured from the date of this Report.

[2]For delivery within one year. This category excludes material deliverable within one year under other than spot or near-term contracts.

Projects removed since last month: 2193, 2484.

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CURRENT MARKET DATA

URANIUM DEMAND
(November 30, 1984)

Nuexco Project Number	Delivery Period[1] (Thousands of Pounds U_3O_8) Spot or Near-term[2]	Intermediate or Long-term	Remarks
Inquiries to Purchase:			
ACTIVE			
2419B*	60	—	UF_6
2533*	300	—	
2539*	125	—	
2548*	300	—	
2568*	50	—	
2590*	475	—	U_3O_8 or UF_6
2217*	—	1,000 per year	1989-95
2442	—	4,000	1986-95
2507	—	600	1987-89
2540*	—	400 per year	1989-94
2555	—	150 per year	1986-91
TOTAL:	1,310		
INACTIVE			
2329	500	—	1985
2576	20	—	UF_6
1999	—	50 per year	1985-90
2244	—	350 per year	1987 on
2414	—	150 per year	1987-91
2457	—	350 per year	1988 on
TOTAL:	520		

*New or revised since last month.
[1]Measured from the date of this Report.
[2]For delivery within one year. This category excludes material deliverable within one year under other than spot or near-term contracts.
Projects removed since last month: 2506, 2532, 2563.

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CURRENT MARKET DATA

CONVERSION SUPPLY AND DEMAND
(November 30, 1984)

Nuexco Project Number	Delivery Period[1] (Thousands of Pounds U as UF_6) Within 3 Years	Beyond 3 Years	Remarks
Available for Sale:			
ACTIVE			
2141	1,000	—	
2560	225	—	
TOTAL:	1,225		
INACTIVE			
2051	1,000	—	
2438*	500	250 per year	1985-87
2511	600	700	1986-90
TOTAL:	2,100		

No inquiries to purchase conversion this month.

LOAN SUPPLY AND DEMAND
(November 30, 1984)

Nuexco Project Number	Delivery Period[1] (Thousands of Pounds U_3O_8) Within 1 Year	Beyond 1 Year	Remarks
Available for Loan:			
INACTIVE			
1938	2,000	—	UF_6
2128	700	—	
2139	2,000	—	
2469A	800	—	
2483	550	—	
TOTAL:	6,050		
Inquiries to Borrow:			
ACTIVE			
2453	500	—	
TOTAL:	500		

*New or revised since last month.
[1]Measured from the date of this Report.

No inquiries to borrow this month.

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CURRENT MARKET DATA

SWU SUPPLY
(November 30, 1984)

Nuexco Project Number	Delivery Period[1] (Thousands of SWUs) Spot or Near-term[2]	Intermediate or Long-term	Remarks
Available for Sale:			
ACTIVE			
2100	150	100 per year	
2583*	50	—	
2624*	100	—	
2631*	150	—	
2632*	25	—	
2285	—	300	
2378	—	120	1988
2510	—	50	
2513	—	25	1986
2517	—	150	1986-89
TOTAL:	475		
INACTIVE			
2164*	25	—	
2359	180	—	
2589	50	—	
2531	—	150	1987
2571	—	55	1987
TOTAL:	255		

*New or revised since last month.
[1]Mensured from the date of this Report.
[2]For delivery within one year. This category excludes SWUs deliverable within one year under other than spot or near-term contracts.
Projects removed since last month: 2408, 2580, 2628.

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SWU DEMAND
(November 30, 1984)

Nuexco Project Number	Delivery Period[1] (Thousands of SWUs) Spot or Near-term[2]	Intermediate or Long-term	Remarks
Inquiries to Purchase:			
ACTIVE			
2443*	45	—	
2480*	70	—	
2655*	10	—	
2519	—	30 per year	1987 on
2550*	—	45	1986
2578	—	150	1986
2653*	—	100	1986-90
TOTAL:	125		
INACTIVE			
2543*	25	25	1986
2500*	—	500	1987-90
2512	—	15 per year	1987 on
2585*	—	100	1986
TOTAL:	25		

*New or revised since last month.
[1]Measured from the date of this Report.
[2]For delivery within one year. This category excludes SWUs deliverable within one year under other than spot or near-term contracts.
Projects removed since last month: 2459, 2550, 2604, 2688.

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ANALYSIS & COMMENTARY

OPTIMUM TAILS ASSAY—Part 2

Introduction

This is the second in a series of articles on the enrichment tails assay. Part I (Report 195) covered the theory and economics of the enrichment process, including the method for determining the enrichment tails assay that yields the minimum product cost. This article will show how the tails assay for minimum product cost changes when the unit price of enrichment services depends on the tails assay. The final installment will discuss the dependence of the unit cost of feed material on the tails assay and the true optimum tails assay.

Primary Market SWU Cost Dependence on Tails Assay

The concept of the separative work unit (SWU) was originally devised to provide a standard unit of work that was independent of enrichment and tails assay. In the past, most enrichment services were obtained from primary suppliers that priced their services on this theoretical basis; i.e., so many dollars per SWU.

In the last few years, projections of required enrichment services have been reduced to the point where both the USDOE and Eurodif have excess enrichment capacity. In this period of shrinking load projection, the DOE has become concerned about its fixed production costs. When excess capacity exists, the fixed costs per SWU (for items such as depreciation and development) will be increased whenever the quantity of SWUs delivered are reduced. SWU sales can be reduced by contract cancellations, reductions of requirements, or through the mechanism of the variable tails assay option (VTAO). By increasing their transaction tails assays, customers can fulfill their requirements with fewer SWUs, thus increasing the fixed cost for every SWU produced by DOE.

DOE's VTAO Surcharge

To counteract the loss of SWU sales due to their customers' exercise of the VTAO, DOE instituted a new pricing policy in converting its customers to the new Utility Services enrichment contract (USEC); the Variable Tails Assay Option (VTAO) Surcharge. The VTAO is offered for all deliveries under the USEC contract beginning in 1987. The VTAO surcharge, which increases the unit price for SWU at tails assays above 0.20 weight-percent U_{235} (w/o), is a maximum of 0.7 percent of the base contract price for every 0.01 w/o by which the tails assay exceeds 0.20 w/o.* The resulting SWU cost for USEC deliveries is determined as follows:

$$\text{SWU Cost} = \text{Base Contract Price}[0.86 + (0.7 \times \text{Tails Assay})]$$

[Note: In this equation, tails assay must be expressed in w/o, and is subject to a minimum of 0.20.]

The current Base Contract Price is $135 per SWU, so the total SWU cost ranges from $135 at tails assays of 0.20 w/o (or less), to $144.45 at a tails assay of 0.3 w/o. The effect of the maximum VTAO charge on the cost of enriched product is shown in Figure 1, which shows the cost of a kilogram of 3.50 w/o enriched product for a base SWU price of $135 and feed costs of $50/KgU, with and without the VTAO surcharge. The VTAO reduces the variation of product cost with tails assay, so that the DOE effectively shares any savings for higher tails assays.

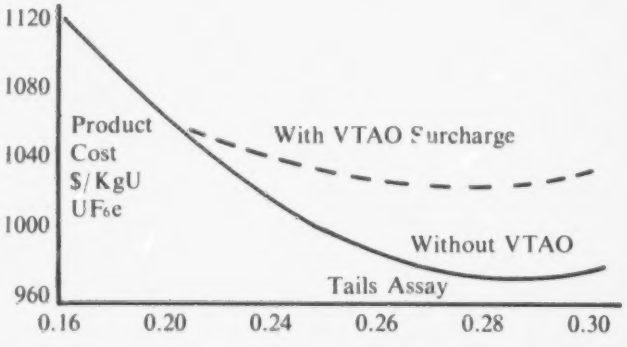

Figure 1. Cost of 3.50 w/o Product as a Function of Tails Assay for Feed at $50/KgU and Enrichment at $135/SWU.

As the VTAO surcharge increases the cost of SWU at higher tails assays, it will reduce the tails assay for minimum product cost. If the maximum surcharge is applied, the optimum tails assay can be found from the equations in the Appendix to this article. The tails assay for minimum product cost with the VTAO surcharge is compared to the tails assay for minimum product cost *without* the surcharge in Figure 2.

The VTAO surcharge makes the tails assay for minimum product cost about 0.03 w/o less than the tails assay

*A significant portion of the DOE's "fixed" cost is the demand charge it pays to its electrical suppliers. As it has been unable to eliminate the demand charge for SWUs (electric power) not taken under higher tails assays, the DOE is passing this cost on to its customers in the VTAO surcharge.

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for minimum cost without the surcharge. As a result, the VTAO surcharge will induce the DOE customers to use more SWU and less feed. The tails assay for minimum product cost with VTAO is also a weak function of the product enrichment, being slightly higher at lower enrichments.

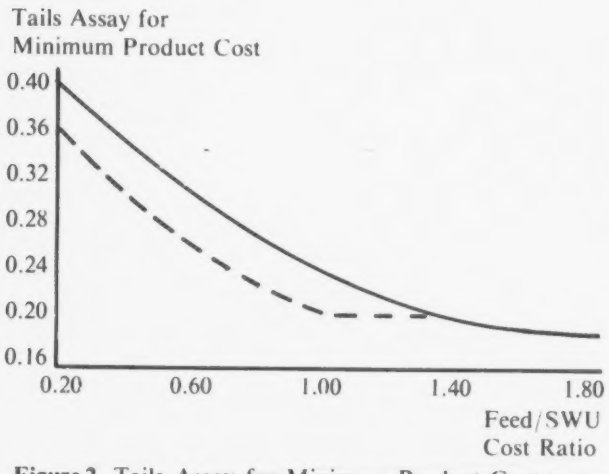

Figure 2. Tails Assay for Minimum Product Cost as a Function of the Feed/SWU Cost Ratio for Natural Uranium Feed at an Enrichment Level of 3.50 w/o.

Secondary Market SWU Cost Dependence on Tails Assay

While most primary enrichment suppliers do not impose a surcharge for SWUs at higher tails assays, the price of enrichment services on the secondary market is often a function of the tails assay. Most secondary market transactions are de-enrichment swaps, wherein a seller holding excess enriched uranium or an unneeded delivery contract swaps enriched product to a buyer in return for cash plus the natural uranium feed theoretically necessary to produce the enriched product. The amount of cash is determined by the number of SWUs theoretically necessary to produce the enriched product, times some established price per SWU. Although the tails assay is technically immaterial in such transactions, its use as the device for computing cash, feed and SWU quantities makes it important.

The material and cash flows in a de-enrichment swap are illustrated in Figure 3. (Report 189, pages 25-27, describes in more detail the mechanics of the de-enrichment swap.) In this example, a one-kilogram quantity of enriched product at 3.50 w/o is de-enriched at 0.3 w/o tails assay. The quantity of feed returned and the number of SWUs purchased from the seller are the Feed Factor and SWU Factor for the given product enrichment and tails assay.

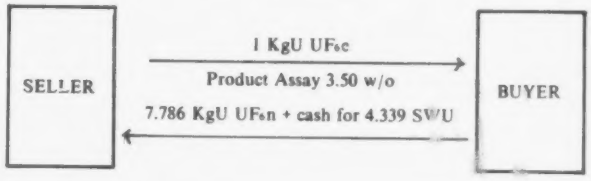

Figure 3. Hypothetical De-enrichment Swap (Using Tails Assay of 0.3 w/o).

The tails assay assumed for the transaction is a variable which should be established by the economic parameters of the parties to the transaction. To establish the appropriate tails assay, we will first look at the economics of the SWU seller.

Secondary Market SWU Prices and Transaction Tails Assay from the Seller's Viewpoint

From an economic viewpoint, the seller is giving up the value contained in his enriched product in exchange for cash plus the value of the returned feed. In the example illustrated in Figure 3, assume that the seller values 3.5 w/o enriched product at $900/KgU, and puts a value of $50/KgU on returned feed material. At what price should he sell the contained SWUs?

The *breakeven SWU price* is defined as that which would produce the same overall cost of product as if the sale had not been made. Transforming the equation for cost of enriched product, the breakeven SWU price is derived as:

$$\text{Breakeven SWU Price} = \frac{\text{Product \$/KgU} - \text{Feed \$/KgU} \times \text{Feed Factor}}{\text{SWU Factor}}$$

At a tails assay of 0.30 w/o, the resulting equation becomes:

$$\text{Breakeven SWU Price} = \frac{\$900 - \$50 \times 7.786}{4.339} = \$117.70$$

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Thus, at a tails assay of 0.30 w/o, the seller needs to obtain a price *greater than* $117.70 to have any incentive to make the deal.

Similarly, if the seller chose a tails assay of 0.20 w/o, the SWU price needed to break even would be $106.60. If the SWU price were established so that the seller received the same total value for his enriched product, he should be indifferent to the transaction tails assay of the de-enrichment swap. Such an indifference curve of SWU price versus tails assay, which can also be labeled the "Seller's Constant Product Value Curve," is shown in Figure 4.

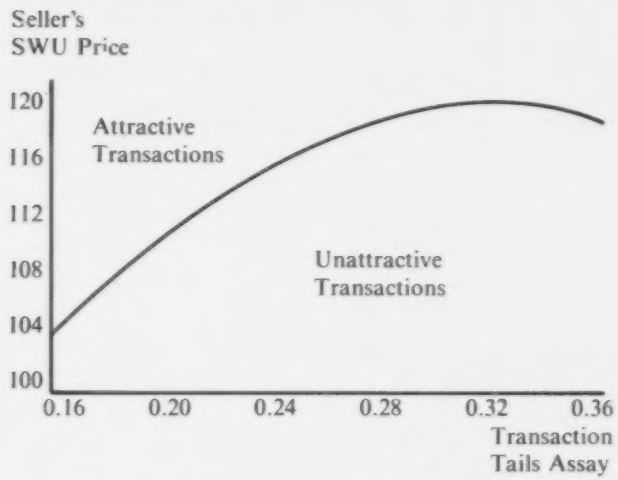

Figure 4. Seller's Constant Product Value Curve.

Any transaction having a SWU price above the Constant Product Value Curve will be attractive to the seller, as he will receive more than his established value of $900/KgU for his enriched product.

Secondary Market SWU Prices and Transaction Tails Assay from the Buyer's Viewpoint

Buyers in the secondary SWU market are likely to be utilities that do not have firm commitments to purchase enrichment services from a primary SWU supplier, and wish to take advantage of the lower prices offered on the secondary market. Assuming that the buyer holds natural uranium, the de-enrichment swap allows the buyer to purchase the required enrichment product in a manner similar to the primary enrichment services contract; exchanging cash and feed material for the enriched product.

Continuing the example started above, assume for the moment that a buyer needs 3.50 w/o enriched product, and has a marginal feed value of $100/KgU. His feed value is higher than the current market, but may be based on the historical cost of inventory material or on future deliveries contracted for at a time when prices were higher.

The buyer receives an offer from the seller for a de-enrichment swap for $117.70 per SWU at 0.30 w/o tails. The buyer's product cost under this offer would be:

$$\text{Product Cost} = \text{Feed Value} \times \text{Feed Factor} + \text{SWU Cost} \times \text{SWU Factor}$$

$$= \$100 \times 7.786 + \$117.70 \times 4.339 = \$1289/\text{KgU}.$$

To compare this enrichment offer to others made at different tails assays, a Curve of Constant Product Cost for the buyer can be constructed in a manner similar to the seller's Constant Product Value Curve, using $1289/KgU for the product cost and $100/KgU for the feed. This Constant Product Cost Curve is shown in Figure 5. If the buyer can buy SWU at prices below this constant cost, or buyer's indifference curve, he will have reduced his fuel costs.

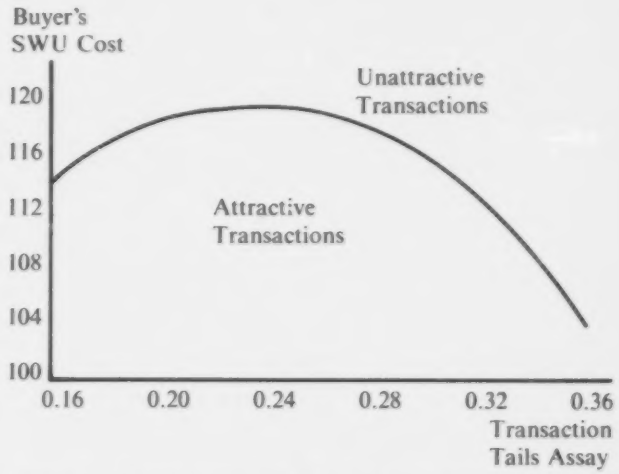

Figure 5. Buyer's Constant Product Cost Curve.

A Successful Secondary SWU Transaction

If the buyer receives no other offers with SWU prices below the constant cost curve in Figure 5, the seller has made the most attractive offer in this hypothetical example. However, even this offer may be improved by the selection of an appropriate transaction tails assay.

Superimposing the buyer's and seller's indifference curves in Figure 6, a common area appears where the participants may derive further benefits from the transaction.

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This is the area which is above the seller's Constant Product Value Curve, and below the buyer's Constant Product Price Curve.

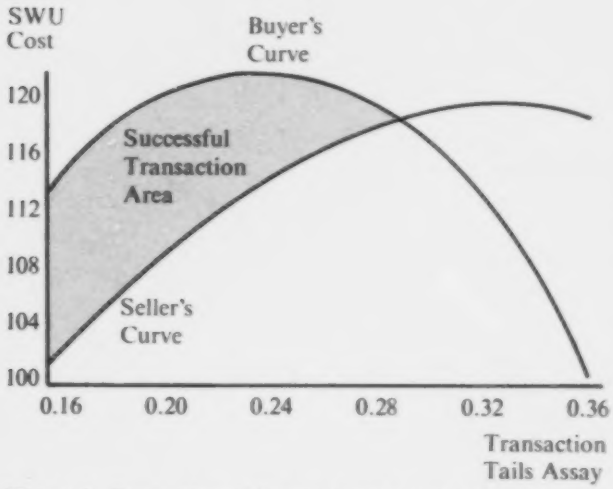

Figure 6. Comparison of Buyer's and Seller's Indifference Curves.

In this example, the largest positive difference between the two curves occurs at low tails assays. If the transaction took place at 0.16 w/o tails, rather than the 0.3 w/o tails offered by the seller, the value added by the tails assay change would be about 13% of the cost of the SWUs.

The Role of the Intermediary

In many cases, the buyer and/or seller have institutional constraints that prevent them from changing the tails assay, and so an intermediary, or market maker, is used to facilitate the transfer. The intermediary can buy the SWU from the seller at his offered tails assay and sell the equivalent SWU to the buyer. The current secondary SWU market is a buyer's market, so the seller usually makes a firm offer, which is then optimized by the intermediary and offered to the buyer as a better value than the unaltered transaction. Assuming that the intermediary (who will receive a commission from the SWU seller) passes on all of the benefits of the tails assay change to the buyer, this transaction is illustrated in Figure 7.

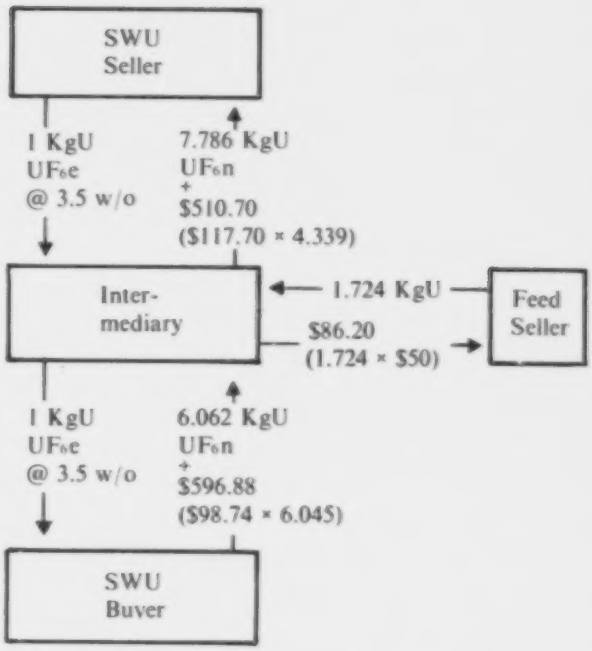

Figure 7. De-enrichment Swap with Intermediary (Change from 0.3 w/o to 0.16 w/o tails).

The intermediary receives more cash from the buyer than he pays to the seller, but the feed quantity to be returned to the seller is greater than that provided by the buyer. The intermediary uses the extra cash to purchase the additional feed required from a fourth party or supplies it from his inventory. The intermediary is the party that is changing the tails assay, and his marginal feed value (usually near the spot market price) determines the Constant Product Value Curve. With an intermediary who passes on all of the benefits of the tails assay change, the buyer's net product cost is shown as a function of tails assay in Figure 8.

The buyer's tails assay for minimum product cost is less than 0.16 w/o. At 0.16 w/o tails the buyer's product cost is $1203/KgU as enriched UF_6, compared to $1289 for the seller's offer at 0.30 w/o tails. While the cost continues to decrease at lower tails assays, this is beyond the range where past transactions have taken place, and some accounting questions may need to be addressed.

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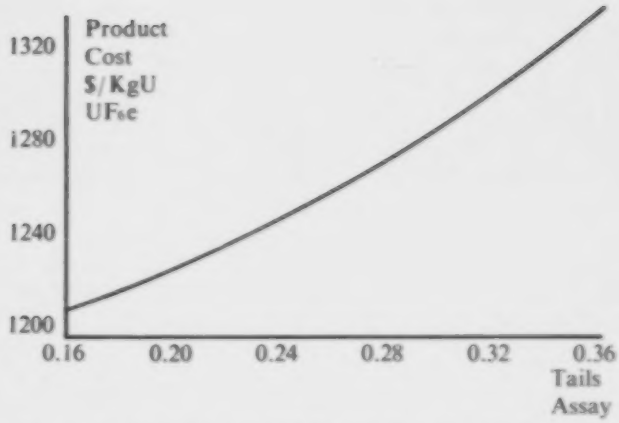

Figure 8. Buyer's Cost of 3.50 w/o Product on the Secondary SWU Market.

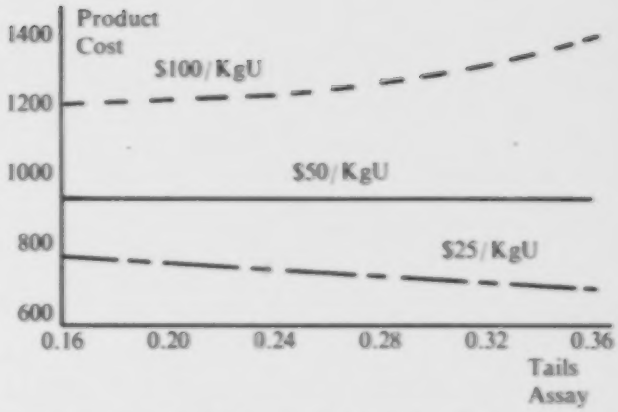

Figure 9. Cost of 3.50 w/o Product for Various Feed Costs (Seller's SWU Price Based on $50 Feed).

If the buyer had used the classic concept of the optimum tails assay (the tails assay for minimum product cost at a *constant* SWU price), with $117 per SWU and $100/KgU feed, he would have concluded the optimum tails was 0.24 w/o, with a corresponding product cost of $1271/KgU.

Analysis

While the above example shows that the transaction tails assay can have a considerable effect on secondary market SWU purchases, the reader has probably observed that the driving force behind the cost improvement was the relatively high value assigned to feed material by the SWU buyer. The final essay in this series will show that the proper feed value to use in tails assay optimization is the expected market value for *replacement* feed, discounted from the time of replacement. As more participants in the market begin to recognize this fact, they will begin to use nearly the same indifference curves, and the *real* value of secondary market SWU will become almost independent of tails assay. This point is illustrated by Figure 9, where the net product cost to the buyer shown in Figure 8 is repeated for other marginal feed values.

Note that when the buyer and seller use the same feed value, the enriched product cost is not a function of tails assay at all. In a rational market, there will be differences in marginal feed value due to varying perceptions of future uranium costs, but they should not be of the magnitude used in Figure 9. If the sellers or buyers deviate from the Constant Product Value Curve based on the spot market value of feed material, an intermediary should be able to adjust the tails assays with feed sold from or to the spot market to give them the benefits of that difference.

Summary

Part 2 of the tails assay article has focused on some of the market conditions that make the cost of SWU depend on the enrichment tails assay, and developed the cost of enriched product as a function of tails assay under these conditions. The results of these analyses show that the tails assay for minimum product cost is a complex function of the economic parameters for both the SWU buyer and the SWU seller. General rules developed for past primary market transactions simply *do not apply* to the secondary SWU market.

Because of the complexity of these functions and a variety of contractual and institutional constraints on the buyers and sellers, there may be an increasing role for intermediaries who are familiar with these relationships and can use arbitrage techniques to resolve the conflicts between the economic parameters of the primary parties.

One of the primary conclusions from Part 2 is that the variation of enriched product cost with tails assay is most sensitive to the cost of feed material used in the evaluation. The final essay will address this issue by focusing on the fuel cycle economics of utilities as SWU buyers and secondary market sellers.

Appendix

Tails Assay for Minimum Product Cost with Maximum DOE VTAO Surcharge

The following series of implicit equations can be solved by iteration on a computer or programmable calculator. In this series of equations, the feed is assumed to be 0.711

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w/o, and the assays are in units of weight percent, in contrast to the other equations in this article which use assay as weight fractions (weight percent = weight fraction × 100).

$$A = (\text{Tails w/o} / 50 - 1) \times (0.711 - \text{Tails w/o})$$

$$B' = 4.868883 - (\text{Cost Ratio}) + 0.985780 \times \text{Ln}[\text{Tails w/o} / (100 - \text{Tails w/o})]$$

$$S = 0.7 \times \text{SWU Factor} \times (0.711 - \text{Tails w/o})^2 / [(\text{Enrichment w/o} - 0.711) \times (0.86 - 0.7 \times \text{Tails w/o})]$$

$$\text{Tails w/o} = A \times 100 / [(100 - \text{Tails w/o}) \times (B' - S)]$$

The above relationships assume a VTAO credit for tails assays less than 0.2 w/o. As a result, they are incorrect for tails less than 0.2 w/o, and must be adjusted to the lesser of 0.2 w/o or the tails assay for minimum product cost without the credit (Report 195).

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FOCUS

SWEDEN

Introduction

Sweden has emerged as a world leader in the use of nuclear energy and the development of nuclear technologies. Ten reactor units now generate electricity for commercial sale, and two 1050-MWe BWRs are scheduled to begin commercial operations by mid-1985. Thus, while Sweden's population is only 8.3 million, its operational nuclear generating capacity is surpassed by that of only six other nations.[1]

Like many industrialized nations, Sweden's principal motivation for developing nuclear energy has been to reduce the percentage of energy requirements supplied by imported oil. Nuclear power and hydroelectric power now generate more than 95 percent of the country's electricity (Table 1), and electricity use has been growing steadily in recent years. Sweden possesses substantial low-grade uranium reserves that could be exploited in the event of a foreign uranium supply cutoff. The three principal nuclear power utilities currently import uranium from a range of sources, and have participated actively in international markets in order to minimize fuel costs.

Table 1

1983 ELECTRICITY CONSUMPTION BY SOURCE IN SWEDEN

Source	Generation (TWh)	Percent of Total
Hydroelectric	62.3	59
Nuclear	39.2	37
Coal and other	4.0	4

Source: *Swedish Nuclear News,* March 1984.

Nuclear Power Utilities

Because it lacks significant known resources of oil, coal or natural gas, Sweden depended on oil imports for over 80 percent of energy requirements in the early 1970s. The desire to reduce its energy trade deficit and diversify the nation's energy base was the principal motive for developing nuclear power. Thus far, nuclear power has replaced more than 10 percent of total energy consumption. In addition, since the early 1970s, new hydroelectric installations, imports of hard coal, and the use of forest products for heating have supplanted a further 15 percent of energy needs; oil imports now supply only 55 percent of Sweden's total energy. A government bill passed in 1981 and recently reaffirmed by the Swedish parliament (Riksdag) calls for the continued reduction of oil use to 40 percent of total energy consumption.

The four commercial nuclear power installations in Sweden have a total of 12 reactors (Table 2). The Oskarshamn plant (Figure 10), the site of the first commercial unit built in the country, is owned and operated by OKG, a consortium of private companies led by Sydkraft (38 percent). All three of the Oskarshamn units are Asea Atom BWRs with turbine generators built by Stal Laval. (The industrial conglomerate Asea and the Swedish government share ownership of Asea Atom; Stal Laval is a subsidiary of Asea.) Oskarshamn Units 1 and 2 achieved average capacity factors of 81.7 and 80.2 in 1983, and Unit 1 was the best performing reactor in Europe in the first half of 1984, achieving a capacity factor of 93.6. OKG anticipates fuel loading at Unit 3 in December 1984, with commercial operation in mid-1985. Oskarshamn Unit 3 and Forsmark Unit 3 are the largest BWRs Asea Atom has sold to date.

Sydkraft is the second largest electric utility in Sweden after the State Power Board (SSPB). The Barseback plant near Malmo (Figure 11) is operated by the Sydkraft subsidiary Sydsvenska Varmekraft AB. Both 570-MWe Barseback units achieved high availability and capacity factors in 1983; Unit 2 had a capacity factor of 89.4 in the first half of 1984.

SSPB's four-unit Ringhals plant, located just south of Goteborg on the west coast, is the largest nuclear power facility in Sweden. Ringhals Units 2, 3 and 4 are Westinghouse PWRs, the only commercial reactors in the country not supplied by Asea Atom. Ringhals Unit 4 began commercial production in November 1983; on January 23, 1984, all four Ringhals units operated at 100-percent power for the first time (3,350 MWe net). SSPB also is the majority owner (74.5 percent) and operator of the Forsmark plant north of Stockholm. The utility received a fuel loading license for Forsmark Unit 3 in October, and expects to begin full power generation in mid-1985.

[1]The six nations having greater operational capacity are the USA, France, the USSR, Japan, the Federal Republic of Germany, and the United Kingdom. Canada currently has a larger installed capacity, but its Pickering Units 1 and 2 are not in service.

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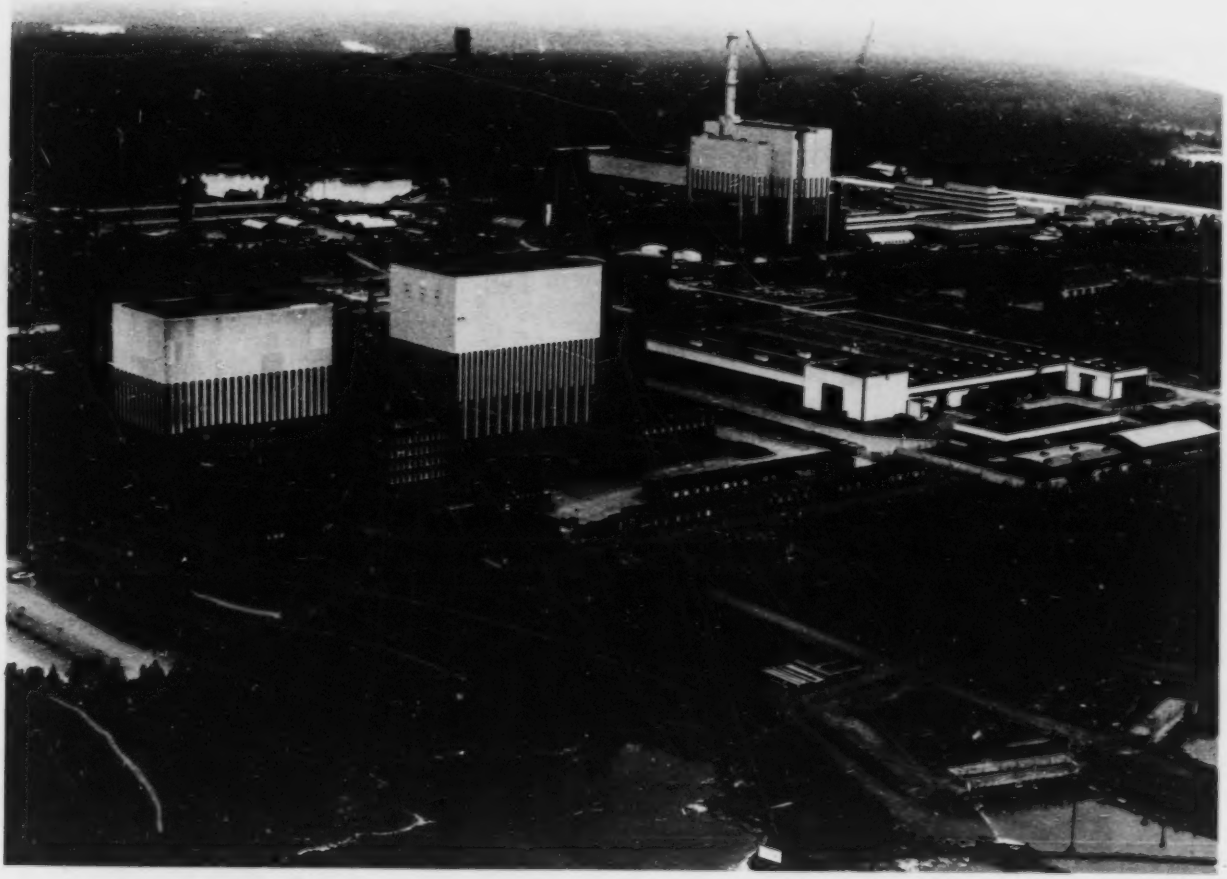
Nuclear Power Politics

In March 1980, shortly after the Three Mile Island incident in the USA and amid widespread anti-nuclear sentiment throughout the Western world, Swedish voters accepted a popular initiative calling for the eventual phasing out of commercial nuclear power in their nation. A year after the passage of the referendum, the Riksdag established 2010 as the year in which the goal would be achieved. The precise schedule for the phase-out has not yet been determined, nor have specific plans been formulated for the construction of replacement power facilities. A Riksdag committee concluded earlier this year that implementation of the decision is feasible, particularly if the nation achieves a reduction in total energy consumption over the next several decades, although not without considerable costs. The committee estimated that if all 12 units are still functioning well by the turn of the century and the ban is implemented, taxpayers could end up paying up to $1 billion for each year the units would have remained in operation.

At this time it is difficult to predict whether the nuclear power phase-out actually will transpire. In recent years, the strength of Sweden's conservative political party, the Moderates, has grown to 28 percent, while that of the anti-nuclear green party, the Centre, has declined to approximately 12 percent. The Centre Party led a coalition government in the late 1970s and unsuccessfully attempted

Figure 10

OSKARSHAMN NUCLEAR POWER PLANT



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to terminate the utilities' nuclear power projects. It appears at the present time that Sweden may be moving in the political direction of other Western nations that have encouraged the growth of nuclear power through new economic policies.

The majority Social Democratic Party, led by Prime Minister Olof Palme, historically has taken a somewhat ambivalent position toward nuclear energy. The government taxes oil, coal and nuclear-generated electricity to subsidize soft energy sources. However, it is unlikely such sources will ever supplant a substantial percentage of growing energy needs. Ultimately, environmentally-conscious Swedes may decide it is not in their best interest to replace nuclear power with more hydroelectric dams, or with fossil fuel plants that require vast imports of coal or oil, and which have substantially more adverse environmental impacts.

Waste and Safety Issues

Two existing laws governing nuclear energy place heavy emphasis on the assurance of safe and effective means to close the fuel cycle. The Nuclear Stipulation Law, which came into effect in May 1977, stipulated that fuel may not be loaded in a reactor until the reactor operator has shown the government authority that high-level waste will be handled and disposed of safely. It also required utilities to obtain reprocessing contracts before nuclear units could be licensed. The 1984 Act on Nuclear Technical Activities, which in February of this year replaced several laws including the 1956 Atomic Energy Act, removes the requirement to have reprocessing contracts in place (there is still a requirement to show the capability for eventual reprocessing) and dictates that each reactor owner must carry out a comprehensive research and development program at least six years long to ensure safe disposal of wastes and safe plant decommissioning. Approximately one-third of the utilities' accountable fuel costs finance future expenses related to the back end of the fuel cycle.

In their efforts to resolve waste management issues, the

Table 2

COMMERCIAL NUCLEAR POWER PLANTS IN SWEDEN

Unit	Utility	MWe (net)	Type	Commercial Operation Date	1983 Capacity Factor
Oskarshamn 1	OKG[1]	440	BWR	Feb 1972	81.7
Oskarshamn 2	OKG	595	BWR	Dec 1974	80.2
Oskarshamn 3*	OKG	1050	BWR	Nov 1985	—
Barseback 1	Sydkraft[2]	570	BWR	Jul 1975	80.2
Barseback 2	Sydkraft	570	BWR	Jul 1977	75.2
Ringhals 1	SSPB[3]	750	BWR	Feb 1976	49.7
Ringhals 2	SSPB	800	PWR	May 1975	56.2
Ringhals 3	SSPB	915	PWR	Apr 1981	36.3
Ringhals 4	SSPB	915	PWR	Nov 1983	61.4[4]
Forsmark 1	FKA[5]	900	BWR	Dec 1980	75.2
Forsmark 2	FKA	900	BWR	Jul 1981	69.5
Forsmark 3*	FKA	1060	BWR	May 1985	—
Total MWe Capacity		9,465			

*Presently under construction. Forsmark 3 has received a fuel loading license.
[1]Sydkraft AB owns 38 percent of OKG.
[2]Sydvenska Varmekraft AB, a subsidiary of Sydkraft AB, is the owner and operator of the Barseback plant.
[3]SSPB = Swedish State Power Board (Vattenfall).
[4]Capacity factor for between November 11, 1983, and December 31, 1983.
[5]FKA = Forsmarks Kraftgrupp AB. SSPB owns 74.5 percent of FKA and is the operator and fuel purchaser for the plant.

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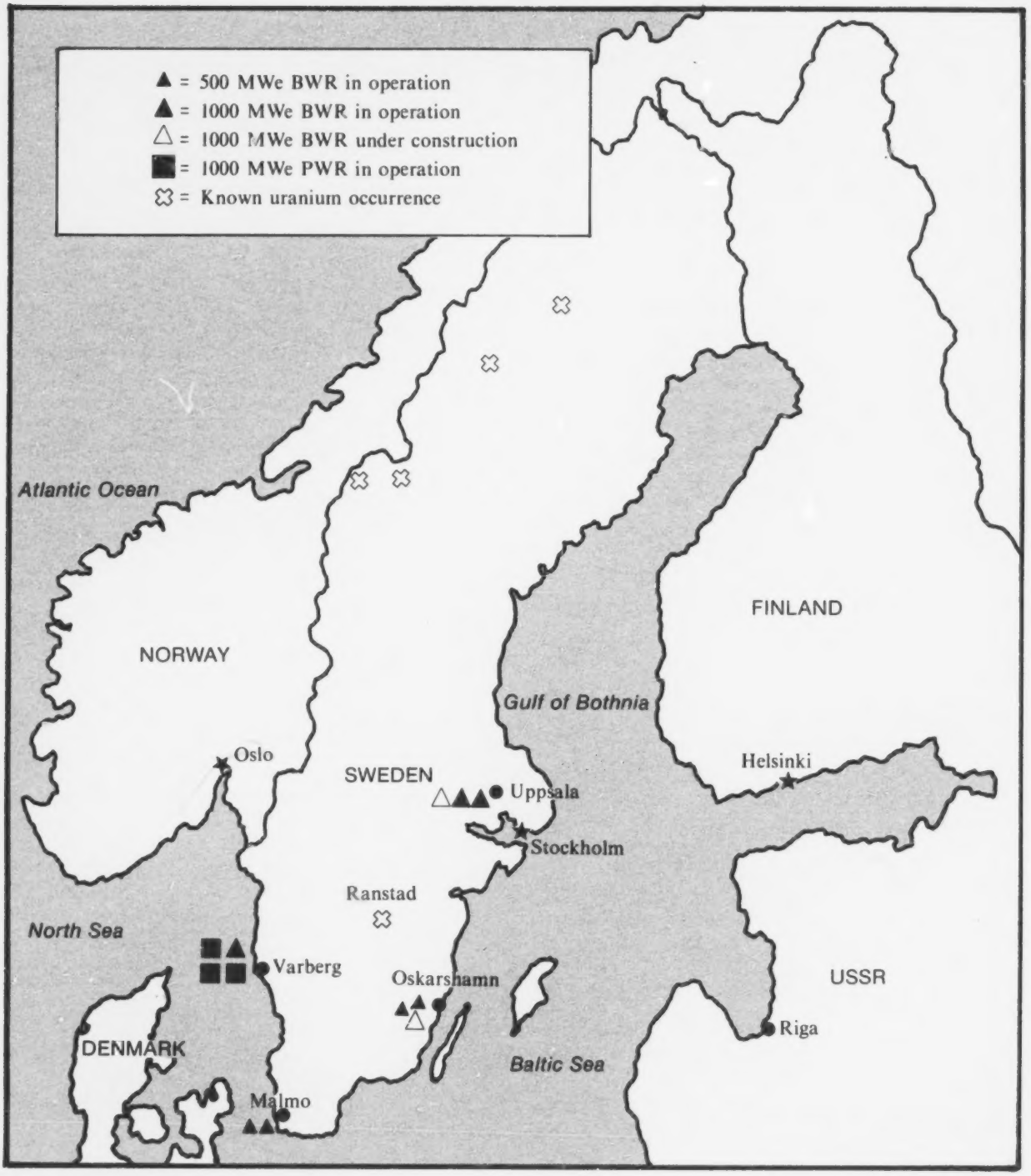
Figure 11

SWEDEN AND NEIGHBORING COUNTRIES



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four nuclear power utilities have pooled resources to form the Swedish Nuclear Fuel and Waste Management Company, SKB (Svensk Karnbranslehantering AB) (Table 3). SKB has organized Sweden's four principal waste management projects:

1. **SFR:** A facility for the permanent storage of all low and medium-level wastes, to be located under the seabed near the Forsmark plant. Sitework began early in 1984.
2. **CLAB** (Central Temporary Storage Facility for Spent Fuel): A facility for the intermediate storage of spent fuel, located in a rock cavern at Simpevark, near the Oskarshamn plant. SKB commissioned OKG for both construction and operation of CLAB. The facility is now virtually complete; shipments will begin arriving early in 1985.
3. **M/S Sigyn:** A special ship designed for the transport of spent nuclear fuel. It began operating in 1982, taking shipments for reprocessing to Cogema and BNFL, and will begin shipments to CLAB in the coming months.
4. **SFL:** A repository for the final storage of high-level and long-lived radioactive wastes. The Nuclear Power Inspectorate and the National Institute of Radiation protection have approved a proposal for SFL that followed years of research and development. Wastes will be stored in special copper cannisters within a geologic repository 500 meters underground, to be backfilled with bentonite.

Table 3

OWNERSHIP OF SKB[1]

Utility/Company	Percent Share
OKG	22
Sydkraft[2]	12
Swedish State Power Board	36
Forsmarks Kraftgrupp AB (FKA)	30

[1]SKB = Svensk Karnbranslehantering, the Swedish Nuclear Fuel Supply Company. SKB owns most of the facilities in Sweden having to do with the back end of the fuel cycle. It also controls an enriched uranium stockpile equivalent to approximately one year forward consumption for the operating nuclear units, and conducts exploration for domestic uranium.

[2]Sydkraft AB owns 12 percent through its subsidiary Sydsvenska Varmekraft AB.

Fuel Supply

Sweden possesses the largest known uranium resources in Western Europe. The most well-known deposit is found at Ranstad in the south central part of the country. It is a large, low-grade (0.03 percent), homogeneous orebody located in alum shale, having a recoverable potential of some 300,000 metric tons U_3O_8. No commercial quantities of uranium have been mined from Ranstad since 1975, although a company formed to exploit the deposit had been evaluating it for several years. The principal obstacles to commercial development are local opposition and low ore grade; in the event of a foreign uranium supply cutoff, both obstacles could be overcome. SKB and the Swedish government have prospected for uranium throughout the country, and a group of low-grade deposits has been identified near the Arctic Circle. SKB completed a long evaluation project at Pleutajokk in September 1981. During 1983, test drilling at Lilljuthatten in the municipality of Krokom indicated a U_3O_8 reserve of at least 2,000 tonnes, with average ore grade exceeding 0.1 percent. (Swedish uranium occurrences are reviewed in Report 169, September 1982.)

Since 1981, OKG has owned 1 percent of ERA (Energy Resources of Australia), and the utility took delivery of over 800,000 pounds U_3O_8 from the Ranger mine in 1983. Enrichment services for Oskarshamn Units 1 and 2 are covered by 3.5-year Requirements contracts with DOE; a contract between SKB and Techsnabexport provides enrichment for Unit 3. OKG chose not to convert to DOE's Utility Services enrichment contract (USEC), and has purchased some SWUs from secondary market sources. One large secondary market transaction in late 1983 involved a sale of some 1.3 million SWUs, for delivery between 1986 and 1990, from ENEL (Ente Nazionale per L'Energia Elettrica) to the Swedish utilities. OKG will receive approximately one-third of the ENEL SWUs.

Both Sydkraft and SSPB purchase most of their natural uranium from Canadian sources, and principally from SMDC (Saskatchewan Mining Development Corporation). SSPB buys fuel for the three Forsmark units as well as the Ringhals plant. Both Sydkraft and SSPB have contracts with DOE for enrichment services, while Sydkraft converted its Requirements contracts and five AFCs (Adjustable Fixed-commitment contracts) to the USEC. A government bill passed in June 1982 called for the stockpiling in Sweden of enriched uranium equivalent to 35 TWh of nuclear-generated electricity. At the present time, SKB manages the stockpile.

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AUSTRALIA

The Chairman of Western Mining Corporation (WMC) announced that full production of the Olympic Dam project (Roxby Downs) will be achieved in stages because of limited uranium market opportunities before 1990. Detailed development plans for the project will be available only after the completion of the feasibility study sometime next year. WMC and BP Australia are funding the A$150 million study.

Initial production of the Roxby Downs ore body would concentrate on high-grade gold areas. The Chairman acknowledged that the project had been granted development status by the Australian Labor Party and WMC is now in a position to pursue marketing discussions. No decision has been made on whether the uranium will be marketed jointly or separately. Although the company strongly reaffirmed its commitment to uranium mining and the Roxy Downs project in particular, it appears that a large-scale development will be delayed for some time unless a dramatic turnaround in the copper and uranium markets occurs. The recent focus on high-grade gold ores, however, could provide sufficient leverage to permit a smaller-scale operation to begin before 1990.

JAPAN

The Federation of Electric Power Companies (FEPC) continues to plan for the construction of enrichment, reprocessing, and low level waste storage facilities at a common location in the northern part of Japan's main island of Honshu (Report 193, September 1984). The FEPC has announced that a new company will be formed to own and operate the enrichment and waste storage facilities. The establishment of the company is scheduled for March 1985. Ownership will include the participation of approximately 50 nuclear-related companies centered around the nine private utilities in Japan.

Japan Nuclear Fuel Services (JNFS) will be responsible for construction and operation of the new facility for reprocessing of spent nuclear fuel. JNFS was organized by the utilities in 1980 for that purpose.

Report No. 194 updated the status of Japan utility nuclear power plants in operation, under construction, and planned. Since then, several units have made considerable progress. In October, Kansai Electric achieved criticality at its 870-MWe Takahama Unit 4 (PWR), and Tokyo Electric Power's (TEPCO) Fukushima Unit II-3, an 1100-MWe BWR, also achieved criticality. Commercial operation dates are August and July 1985 respectively. With successful operation of Takahama Unit 4, Kansai Electric will have approximately 3400-MWe capacity at its four-plant Takahama site. TEPCO also is proceeding with plans to license Kashiwazaki Units 3 and 4, both 1100-MWe BWRs. TEPCO will initiate license hearings in the near future and hopes to begin construction in 1987. TEPCO has scheduled commercial operation dates of July 1993 and July 1994.

Kyushu Electric has received license approval for its two 1180-MWe PWRs, Genkai Units 3 and 4. Construction on these units will start in the fall of 1985 with commercial operation scheduled for March 1993 and March 1994. Kyushu has also disclosed its intention to develop a third multiple plant site in addition to its Genkai (four PWRs) and Sendai (two PWRs) sites. Possible locations for new plants, which would not enter operation until the mid-1990s, are in the Saga and Nagasaki areas of Kyushu Electric's territory.

Also, Hokkaido Electric officially has begun construction of its twin 579-MWe PWR plants, Kyowa-Tomari Units 1 and 2.

UNITED STATES

Uranerz Exploration & Mining Ltd. of Canada and UNC Resources Inc. (UNC) have reached a settlement following countersuits filed over a disputed uranium supply contract. The two parties settled out of court several days before a jury trial was set to begin in federal court.

The supply contract, which UNC unilaterally abrogated early in 1984, was to have provided 2.3 million pounds U_3O_8 for delivery between 1984 and 1986. UNC cited "disagreements with the supplier" as the reason for the contract cancellation.

Trial on the countersuits was scheduled to begin on November 13. On November 8, in the US District Court for the Eastern District of Virginia at Alexandria, attorneys filed a motion to dismiss the case. Under the settlement UNC agreed to pay Uranerz $16.4 million.

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RAW MATERIALS

UPDATE—URANIUM RESOURCES IN SOUTH AFRICA

Introduction

The Nuclear Development Corporation (Pty) Ltd. (NUCOR) reevaluated uranium resources in South Africa in 1983. (See Report 193, page 25.) Reasonably Assured Resources (RAR) and Estimated Additional Resources (EAR)[1] based on an estimated production cost of US$30 per pound U_3O_8, are estimated at 343,000 tonnes U_3O_8, down about 14 percent from the 1981 estimate of 392,000 tonnes. The decrease is due primarily to reclassification of approximately 35,000 tonnes into a higher cost category, and a direct reduction of 14,000 tonnes produced in 1982 and 1983. Table 4 shows the distribution of resources among the five different host environments, including RAR and EAR classified in the $30–50/lb. U_3O_8 category.

The first four environments listed represent different geologic provinces where uranium occurs as an important constituent of a particular rock type; the fifth occurrence relates to unrecovered uranium contained in impounded gold slimes tailings accumulated during past gold recovery operations. Figure 12 is a map showing the geographic location of the uranium resource areas.

Uranium in the Witwatersrand conglomerate is produced from the gold/uranium mines located in five major mining areas of the Witwatersrand Basin. Uranium production from the area began in 1952, gradually increasing to 5,841 tonnes U_3O_8 in 1959 when 26 uranium-producing mines supplied ore for 17 recovery plants. Production reached an all-time high in 1980 when 21 mines supplying ore for 19 recovery plants produced 7,247 tonnes U_3O_8.

All uranium production in South Africa originated from Witwatersrand Basin mines until 1971. Presently, 97 percent of uranium produced in South Africa comes from the gold/uranium-bearing conglomerates, plus a small amount produced from reworked tailings within the Witwatersrand Basin. The remaining three percent is produced by the Palabora Mining Company Ltd. as a by-product to copper mining from the Palabora Igneous Complex located in the Letaba district, Northeastern Transvaal Lowveld. There is no production from the other resource areas, most of which remain to be fully evaluated.

[1]Resource classification conforms with the NEA/IAEA definition. RAR includes uranium that occurs in known mineral deposits; EAR refers to uranium in addition to RAR that is expected to occur, based on geologic evidence.

Uranium Resources

Witwatersrand Conglomerates—The Witwatersrand sedimentary system of Early Proterozoic age is one of the world's major sources of gold and uranium. Gold was discovered in the quartz-pebble conglomerates of the system in 1886. Gold mining commenced immediately and progressed rapidly in the following years. Exploration and mining determined the existence of gold values in conglomeratic beds, called reefs, at different depths throughout the system. Continuity and correlation of reefs became important to continued property development within the basin. Total ore reserves today are estimated at more than one billion tonnes.

The occurrence of uranium in association with gold ores was first determined through evidence of radioactivity in the late 1880s. However, it was not until 1915 that the extent of the association in multi-occurring reefs was established; in 1923 the radioactive source was identified as uraninite, one of the most important uranium ore minerals. The Government Metallurgical Laboratory initiated studies focusing on the recovery of uranium from gold ores in the early 1940s. The first pilot recovery plant was successfully producing uranium concentrate in 1945. A second and larger pilot plant installed in the milling circuit of the Blyvooruitzicht gold mine in 1949 proved that commercial extraction was practical. A full-scale recovery plant began operating in late 1952.

Not all gold-bearing reefs contain uranium. Some 70 to 80 million tonnes of gold ore are uraniferous, containing approximately 0.20 pounds to over 2.00 pounds U_3O_8 per tonne. The feasibility of unmined ore reserves changes with the economics of either mineral, but primarily with gold. As the value of gold increases, additional lower grade ore may be considered minable; likewise, as gold values decrease, the lower grade ore becomes uneconomical. Uranium resources can change accordingly as illustrated by the shift of 35,000 tonnes recently reclassified into a higher cost category.

The sediments of the Witwatersrand system were deposited in a structural basin bounded on the northwest and southwest by faulting. Downwarping toward the basin center and to the southeast created the deepest section of the basin where sediments are approximately 7,600 meters thick. The important mines are located along the shallower northwest and southern tip of the basin. Present mining depths vary from 600 meters to over 3,700 meters.

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The Witwatersrand sequence was deposited unconformably on Archean basement rocks as a series of coarse sandstone units interbedded with siltstones and conglomerates. The irregular depositional sequence formed as fluvial fans, deltas, and channel fill. Gold and uranium mineralization are limited to certain conglomerate beds (reefs) in a 4,000-meter-thick section of the middle portion of Witwatersrand sediments.

Important mineralization is found in the matrix of conglomerates, in sand stringers containing moderate to heavy amounts of pyrite, along contact zones of shale and quartzitic beds, and in carbon/shale seams related to planes of unconformity. The minerals were transported as detrital particles deposited during the sedimentary sequence and are therefore syngenetic. However, there is evidence that certain occurrences, primarily gold in the shale and carbon environment, formed later as a result of chloride and cyanide-bearing solution, and biochemically through interaction between the gold (and uranium) and the algal or lichen colonies that developed along edges of channels and deltaic deposition.[2]

Reef systems containing gold and uranium mineralization of sufficient quantity and grade to be economically mined are confined to only 10 or 12 conglomeratic sequences. The lowest reefs include the Ada May (Beisa Reef) in the Orange Free State; the Carbon Leader of the

[2] *Uranium in South Africa,* 1983 Assessment of Resources and Production, page 11, Nuclear Development Corporation of South Africa (Pty) Ltd.

Table 4

SOUTH AFRICA'S URANIUM RESOURCES IN THE RAR AND EAR-1 CATEGORIES[1]
AS OF JANUARY 1, 1983
(Expressed in metric tons U_3O_8)

Principal Deposits or Districts	Reasonably Assured Resources (RAR)[2]		Estimated Additional Resources (EAR)[3]		Percent of Total
	$0–$30/lb. U_3O_8	$30–$50/lb. U_3O_8	$0–$30/lb. U_3O_8	$30–$50/lb. U_3O_8	
Witwatersrand Basin Conglomerates	192,000	59,000	116,000	51,000	77
Palabora	2,000	—	—	—	1
Karoo Sequence	5,000	59,000	1,000	6,000	12
Younger Surficial Sediments	—	1,000	—	—	1
Witwatersrand Basin Tailings	26,000	25,000	—	—	9
TOTAL RESOURCES	225,000	144,000	117,000	57,000	100

[1] Exploitable at costs of less than $50/lb. U_3O_8.

[2] Reasonably Assured Resources (RAR) refers to uranium that occurs in known mineral deposits of such size, grade and configuration that it could be recovered within the given production cost ranges with currently proven mining and processing technology. Estimates of tonnage and grade are based on specific sample data and measurements of the deposits and on knowledge of deposit characteristics. Reasonably Assured Resources have a high assurance of existence and in the cost category below $80/KgU are considered as *reserves* for the purposes of this table.

[3] Estimated Additional Resources–category I (EAR-I) refers to uranium in addition to RAR that is expected to occur, mostly on the basis of direct geological evidence in extensions of well-explored deposits and in deposits in which geological continuity has been established but where specific data and measurements of the deposits and knowledge of the deposits' characteristics are considered to be inadequate to classify the resource as RAR. Such deposits can be delineated and the uranium subsequently recovered, all within the given cost ranges. Estimates of tonnage and grade are based on such sampling as is available and on knowledge of the deposit characteristics as determined in the best-known parts of the deposit or in similar deposits. Less reliance can be placed on the estimates in this category than on those for RAR.

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Figure 12

URANIUM RESOURCE LOCATION MAP OF SOUTH AFRICA

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Main Conglomerate Formation in the Central Rand; the White, Monarch and Bird Reefs on the West Rand; the Vaal Reef in the Klerksdorp Goldfield; the Basal and Leader Reefs in the Orange Free State Goldfield; and the Elsburg Reef in the Central Rand; and their equivalents, the A and B Reefs, in the Orange Free State. All reefs are being mined at present.

Witwatersrand Tailings—The 26,000 tonnes U_3O_8 contained in old mill tailings within the Witwatersrand Basin constitute the second largest uranium resource in South Africa. The uranium content in the slimes tailings averages about 0.10 percent U_3O_8 per tonne. Gold is the primary mineral recovered from the slimes. Uranium and pyrite are secondary minerals, but are important to project economics. The gold and part of the uranium are contained in the pyrite. Sulfuric acid produced from the pyrite is utilized in the uranium recovery process at each conventional recovery plant.

The recovery of minerals from the slimes begins with hydraulic sluicing of the large tailings piles. The slimes feed is passed through grinding ball mills with the exit slurry going to the leaching/cyanidation plant for gold recovery. The filtrate, which contains the uranium, is reslurried with an acidic solution and sent to the leach circuit. The uranium solution is removed by liquid/solid separation (counter current decantation). The pregnant solution is transferred to the solvent extraction circuit; ammonium sulfate is added and the uranium is extracted as ammonium diuranate slurry (ADU). The ADU is trucked to the Nuclear Fuels Corporation of South Africa (Pty) Ltd. (NUFCOR) plant for calcining and packaging.

Palabora Project—Copper mineralization was first noted in the alkaline rocks of the Palabora Igneous Complex in 1870. Eventually, exploration drilling and trenching established an ore reserve of over 100 million tonnes of low-grade copper. The Palabora Mining Company, Ltd. began mining copper ore from the central carbonatite core of the complex in 1964. The project is now one of the largest open-pit mine operations in the world.

The presence of uranium in association with the copper was first noted by the South African Atomic Energy Board in 1952. Uranium was produced as a by-product to copper in 1971 and, by the end of 1983, approximately 1,960 tonnes U_3O_8 were recovered. The rate of uranium production is geared to copper production. Presently, the annual recovery rate of uranium is 200 to 230 tonnes U_3O_8. Recoverable uranium resources at Palabora are estimated at 2,000 tonnes U_3O_8 contained in the remaining minable copper reserves. The source of uranium is the mineral uranothorianite, which occurs in close association with copper sulfide mineralization at an average grade of 0.0035 percent U_3O_8.

During the mineral recovery process, uranium concentrate is added to an acid leach and the uranium liquor transferred to a solvent extraction circuit. The uranium is stripped off in a counter-current mixer unit, followed by precipitation using ammonia gas. The final precipitated product is ammonium diuranate (ADU) slurry, which is then thickened and filtered on a rotary-drum vacuum filter. The filter cake is calcined and packaged for shipment.

Karoo Sediments—Uranium mineralization was first noted in lower Karoo sediments in 1967. The discovery set into motion a competitive exploration effort throughout the southern areas of South Africa. An important discovery was made in 1969 in Lower Beaufort sediments near the community of Beaufort West. Additional mineralization was located in sediments forming an east-west arc over a distance of 1,200 km in the southern Karoo Basin.

The important mineral occurrences are found in rocks of Permian and Triassic age. At least ten of 13 known mineral occurrences are in the Abrahamskraal and Teekloof Formations of the Adelaide Subgroup. The formations consist of interbedded sandstone and mudstone. Uranium mineralization is associated with a variety of depositional environments related to fluvial channeling, braided-stream and delta deposits, and terminal fans.

Mineralization is scattered throughout paleochannel trends as small, discontinuous pods measuring only a few meters in length; thickness varies greatly, reaching a maximum of about 7 meters in several instances. Carbonaceous debris is usually present in each ore pod. The carbonaceous debris and sharp depositional changes combine to create exploration guides to mineralization.

The main ore mineral is coffinite, occurring at grades of up to 0.45 percent U_3O_8; however, the average content of the 6,000-tonne resource is about 0.09 percent U_3O_8. Recoverable molybdenum usually is associated with the uranium, especially where carbon debris is abundant. Other minerals occurring in trace amounts include copper, gelena, zinc, manganese and phosphates. The deposits are not being mined, primarily due to their small size and the unfavorable market for uranium.

Tertiary and Recent Sediments—Small and widely scattered uranium occurrences have been recorded in Tertiary and Recent sediments throughout western South Africa. The potentially uranium-bearing formations were highly prospected in the mid-1970s by utilizing airborne

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radiometric detection devices. Most mineralization was discovered in paleochannels of the major river systems, usually in a calcrete environment, but occasionally in a diatomaceous earth deposit.

The main ore mineral associated with the calcrete is carnotite, found in the sand matrix and as an onion-skin coating on the larger sand grains. Uraninite is the main ore mineral closely associated with organic material in the diatomaceous earth. The average uranium content in deposits of this type is about 0.09 percent U_3O_8. Occurrences of this nature have not been exploited to date.

Miscellaneous Resources—Trace to low-grade amounts of uranium have been discovered in at least three other geologic environments of South Africa. The Springbok Flats coal deposit in the central Karoo Basin contains uranium at grades equivalent to the Karoo sediments. Uranium extraction from the coal has not been attempted on a commercial scale.

Low-grade mineralization has been evaluated in granitic and metamorphic rocks of the Namaqua/Natal belt in the northwestern Cape, in southern Natal and within the Bushveld Complex. The mineralization is disseminated well throughout the rocks, showing slight concentrations in highly fractured zones. Although the occurrences represent extremely large tonnages, each is well below commercial standards in the present condition of the market.

Large-tonnage, heavy-mineral sand deposits located north of Richards Bay on the east coast of South Africa contain monazite. The deposits are about 20 km long by 2 km wide, and contain several hundred million tonnes of mineral-bearing sand. The monazite is produced for export as a by-product of rutile production; however, none of the radioactive minerals are extracted during the rutile recovery operations.

Production Summary—Uranium production of 15.8 million pounds U_3O_8 in 1983 was the highest since 16.0 million pounds were produced in 1980. This increase was a result of a higher mining rate in eight gold/uranium mines in the Witwatersrand Basin, with the greatest increases occurring in the St. Helena–Beisa Section and Western Areas. Driefontein Consolidated showed the largest drop in production. The depletion of surface slimes processed through late 1983 reduced production by more than 22 percent from the 1982 level. In addition, production at Joint Metallurgical Scheme dropped 16 percent.

Since South African uranium production is primarily committed to long-term sales contracts, uranium price variations do not overly influence production schedules. Prices under longer-term contracts tend to fluctuate well above spot market prices. Moreover, despite low gold and uranium prices in the international markets, uranium/gold operations continued to prosper, and a uranium production level coincident to gold production probably will be maintained. (By-product and co-product uranium production from gold mining generally costs less than primary uranium production.) NUCOR projects annual production to be in the range of 15.5 million pounds U_3O_8 to 17 million pounds U_3O_8 through 1995. South Africa will continue to be one of the world's most reliable uranium-producing countries.

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EXCHANGE AND TRANSACTION VALUES SINCE JANUARY 1979

Determined as of the last day of the month indicated

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HISTORICAL MARKET DATA

HISTORICAL EXCHANGE VALUES

Determined as of the last day of the month indicated (US Dollars/lb. U_3O_8)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1968	—	—	—	—	—	—	—	6.35	6.35	6.40	6.45	6.50
1969	—	6.35	6.10	6.10	6.25	6.25	6.20	6.20	6.15	6.15	6.15	6.20
1970	6.30	6.30	6.30	6.30	6.30	6.30	6.30	6.20	6.15	6.15	6.15	6.15
1971	6.20	6.20	6.20	6.20	6.15	6.05	6.00	5.95	5.95	5.95	5.95	5.95
1972	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95
1973	5.95	6.00	6.10	6.20	6.45	6.50	6.50	6.50	6.50	6.50	6.75	7.00
1974	7.70	7.90	8.00	9.00	9.50	10.50	11.50	12.00	12.50	14.00	14.75	15.00
1975	16.00	16.00	18.00	20.00	21.00	23.00	24.70	26.00	26.00	28.50	30.00	35.00
1976	32.50	37.00	39.25	40.00	40.00	40.00	40.00	40.40	41.00	41.00	41.50	41.00
1977	41.35	41.50	41.60	41.60	42.00	42.25	42.25	42.25	42.40	42.75	43.20	43.20
1978	42.90	43.25	43.25	43.25	43.40	43.40	43.40	43.10	43.25	43.00	43.25	43.25
1979	43.25	43.25	43.25	43.25	43.25	43.00	42.70	42.70	42.20	42.20	41.00	40.75
1980	40.00	38.00	35.00	32.00	32.00	31.50	31.50	30.00	28.50	28.00	28.00	27.00
1981	25.00	25.00	25.00	25.00	25.00	24.25	23.50	23.50	23.50	23.50	23.50	23.50
1982	23.00	23.00	22.50	20.75	20.50	19.25	18.25	17.00	17.00	17.50	19.75	20.25
1983	21.50	21.75	22.25	23.25	23.50	23.50	24.00	24.00	24.00	23.50	22.50	22.00
1984	20.50	17.50	17.00	17.75	17.75	17.50	17.50	17.50	17.50	16.00	**15.50**	

HISTORICAL TRANSACTION VALUES

Determined as of the last day of the month indicated (US Dollars/lb. U_3O_8)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1976	—	—	—	—	39.60	39.70	39.70	40.40	40.30	40.60	40.70	40.70
1977	41.30	41.30	41.40	41.50	42.80	42.90	43.00	42.60	42.50	42.80	42.90	42.90
1978	43.10	43.30	43.70	43.60	43.60	43.20	43.30	43.40	43.40	43.60	43.40	43.70
1979	43.60	43.80	43.70	43.40	43.60	43.70	43.70	43.60	4[illegible]	43.60	43.50	42.30
1980	42.00	39.30	38.60	38.40	37.90	37.60	37.30	31.60	30.60	29.00	28.70	27.70
1981	27.20	27.20	27.00	25.70	25.70	24.50	24.40	24.30	23.90	24.10	24.10	24.00
1982	24.00	23.70	23.40	22.60	22.70	21.50	20.30	19.10	17.30	17.00	17.55	18.80
1983	19.35	20.00	21.35	21.40	22.35	22.45	23.50	23.60	23.65	23.65	23.85	23.85
1984	23.05	22.50	19.25	17.90	17.00	16.50	16.60	16.40	16.55	16.05	**15.90**	

HISTORICAL CONVERSION VALUES

Determined as of the last day of the month indicated (US Dollars/lb. U as UF_6)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	1.20	1.20	1.20	1.40	1.15	1.15	1.15	1.10	1.10	1.10	1.20	1.20
1982	1.20	1.20	1.20	1.20	1.00	1.00	1.00	0.90	1.10	1.60	1.45	1.45
1983	1.20	1.40	1.40	1.20	1.20	1.20	1.10	1.10	1.00	0.60	0.60	0.60
1984	0.60	0.30	0.80	0.80	0.80	0.00	0.00	0.80	1.00	1.00	**0.80**	

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AUSTRALIA

	Price Index of Materials Used in Manufacturing Industry—All Groups[1] (1969=100)	Award Rates of Pay Indexes Australia—Adult Males In Mining Wage and Salary Earners, Weekly Rates[2] (1976=100)
1983 Avg.	401.2	181.8
Aug 1983	403.0	180.7
Sep 1983	402.9	180.6
Oct 1983	397.5	188.3
Nov 1983	395.5	188.3
Dec 1983	399.2	188.1
Jan 1984	399.2R	188.6R
Feb 1984	402.5R	188.5R
Mar 1984	403.9R	188.3R
Apr 1984	404.2R	196.2R
May 1984	403.8R	196.9R
Jun 1984	404.9R	196.9R
Jul 1984	408.5R	196.9R
Aug 1984	413.3R	196.9R
Sep 1984	412.1	196.9

P = Preliminary R = Revised since last month

CANADA

		Wage-earner Data: Average Hourly Earnings (C$)[2]					
	Industry Selling Price Index: Manufacturing[1] (1971=100)	Uranium Mines (SIC 057)	Metal Mines* (SIC 051-059)	Mines, Quarries and Oil Wells[3] (SIC 051-099)	Primary Metal Industries Non-ferrous[4] (SIC 296)	(SIC 298)	Chemicals and Chemical Products[5] (SIC 372-379)
1983 Avg.	298.8	—	—**	14.30	—	—	11.17
Sep 1983	301.1	17.66	14.90	14.41	11.99	10.32	11.29
Oct 1983	301.6	17.73	15.27	14.65	11.76	10.03	11.30
Nov 1983	301.8	17.82	15.29	14.67	11.78	10.62	11.38
Dec 1983	302.9	17.84	15.11	14.66	11.86	10.60	11.51
Jan 1984	305.4	17.74	15.27	14.74	11.91	10.84	11.69
Feb 1984	306.6	17.78	15.59	14.90	12.04	10.82	11.51
Mar 1984	308.7	18.05	15.52	14.82	12.14	10.84	11.58
Apr 1984	310.5	18.06	15.83	15.10	11.96	10.34	11.63
May 1984	310.6	18.48	15.64	15.06	12.11	10.16	11.65
Jun 1984	311.0	18.08	15.48	14.80	12.38	10.40	11.66
Jul 1984	312.8R	17.81	15.72	14.92	12.53	10.18	11.82
Aug 1984	312.4R	17.24	15.36R	14.92R	12.44R	10.34R	11.78R
Sep 1984	312.0	17.66P	15.64P	15.13P	12.47P	10.54P	11.95P
Oct 1984	312.1P	—	—	—	—	—	—

P = Preliminary R = Revised since last month

For annual averages prior to 1983, and for notes pertaining to these statistics, see pages 23-26 of Report 190 of June 1984.

*The 1980 average for Metal Mines was incorrectly reported as 10.59. The correct average is 10.58 (see Report 190).

**Two different methods were used in the 1983 "Metal Mines" category in reporting survey data, and Statistics Canada did not publish a 1983 average. The March 1983 figure for the old method was 14.73 and for the new method was 14.84. The published average for 1983 in Report 190 was a Nuexco calculation based on the available monthly statistics for 1983 with the exception of the March figure, where only the 14.84 value was taken into account.

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GOVERNMENT STATISTICS

REPUBLIC OF SOUTH AFRICA

	Average Declared Working Costs per per Metric Ton of Gold Ore Milled (Rand)[1]	Tonnage-Weighted Index of Average Working Costs per Metric Ton of Gold Ore Milled (March 1982=100)[2]	Consumer Price Index[3] (1975=100)[4]	Producer Price Index All Groups[5] (1975=100)	Total Employment in Mining and Quarrying (Code 35)[6]	Total Salaries and Wages in Mining and Quarrying (1,000 Rand) (Code 40)[6]
1983 Avg.	51.87	115.0	262.2	274.8	696,579	3,644,772
Aug 1983	—	—	265.6	278.9	698,984	311,789
Sep 1983	52.92	117.4	267.3	279.4	696,435	312,264
Oct 1983	—	—	270.0	281.0	693,225	311,418
Nov 1983	—	—	271.4	281.6	688,459	317,485
Dec 1983	53.70	119.6	273.2	283.7	690,750	333,595
Jan 1984	—	—	274.7	283.3	689,807	326,619
Feb 1984	—	—	278.4	286.5	702,553	335,906
Mar 1984	55.30	123.1	281.9	288.0	715,628	342,332
Apr 1984	—	—	286.1	290.2	712,963	327,550
May 1984	—	—	288.3	292.6	710,040	327,937
Jun 1984	56.95	126.2	291.2	295.3	717,009	347,121
Jul 1984	—	—	295.1	296.0	717,121	369,964
Aug 1984	—	—	297.0	300.8	721,905	361,357
Sep 1984	60.64R	133.2	299.9	304.1	—	—
Oct 1984	—	—	303.7	—	—	—

UNITED STATES

	Producer Price Index[1]		Consumer Price Index[2]	GNP Implicit Price Deflator[3]	Gross Average Hourly Earnings of Production or Non-supervisory Workers (US$)[4]			
	Industrial Commodities (1967=100)	All Commodities (1967=100)	(1967=100)	(1972=100)	Metal Mining (SIC 10)	Primary Non-ferrous Metals (SIC 333)	Chemicals and Allied Products (SIC 28)	Electric and Electronic Equipment (SIC 36)
1983 Avg.	315.8	303.1	298.4	215.63	12.57	13.43	10.59	8.65
Aug 1983	317.3	304.7	300.3	—	12.54	13.46	10.62	8.62
Sep 1983	317.1	305.3	301.8	216.44	12.62	13.46	10.70	8.73
Oct 1983	318.5	306.0	302.6	—	12.67	13.55	10.79	8.71
Nov 1983	318.3	305.5	303.1	—	12.64	13.56	10.86	8.77
Dec 1983	318.4	306.1	303.5	218.53	12.75	13.33	10.90	8.84
Jan 1984	319.1	308.0	305.2	—	12.67	13.38	10.91	8.88
Feb 1984	320.6	308.9	306.6	—	12.81	13.34	10.90	8.86
Mar 1984	321.9	311.0	307.3	220.58	12.85	13.33	10.95	8.88
Apr 1984	322.5	311.4	308.8	—	12.91	13.30	10.97	8.89
May 1984	323.3	311.7	309.7	—	12.99	13.37	11.02	8.89
Jun 1984	323.9	311.4	310.7	222.40	12.96	13.40	11.03	8.91
Jul 1984	324.0	312.0	311.7	—	13.02	13.36	11.12	8.95
Aug 1984	323.5	310.9	313.0	—	13.10R	13.51R	11.13R	9.00
Sep 1984	322.3	309.5	314.5	224.36	13.23P	13.40P	11.24R	9.08
Oct 1984	323.2	309.4	315.3	—	—	—	11.27P	9.09P

P = Preliminary R = Revised since last month

For annual averages prior to 1983, and for notes pertaining to these statistics, see pages 23-26 of Report 190 of June 1984.

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